

Major Project Report

by Philip Keith Taylor

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Abstract

The aim of this project is create a fully functional cooling system for small devices such games consoles and computers or anything with electrical or electronic components that require forms of cooling that could pro long their life span.

Using a Micro controller as the main brain of the system, with a temperature sensor to read its surrounding temperature and send the value back to micro controller to process the information using analogue to digital conversion.

Once the micro controller has processed the information a Pulse Width Modulation signal is sent from the Micro controller to the DC motor, within certain temperature ranges the motor will increase or decrease its speed. Also a temperature value is being displayed on a LCD with the motors duty output letting the end user know the temperature and the speed of the motor.

Hopefully with end users being able to view internal temperature of their devices it could encourage them to situate the device in a better location, to dust down vents and generally help them look after the device. This will improve the life span of the device and also save the end users money in purchasing new products. After researching I am yet to see a manufacturer that displays internal temperatures, many products have in built fans but do not display the temperature so the client would never be aware that the product is potentially overheating.

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DECLARATION FORM

DECLARATION

I, ...(FULL NAME)..... declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

Signed :

Date :

FORM OF CONSENT

FORM OF CONSENT

I(FULL NAME)..... hereby consent
that my Project, submitted in candidature for the Beng (Hons) electrical and electronic
engineering degree, if successful, may be made available for inter-library loan or
photocopying (subject to the law of copyright), and that the title and abstract may be made
available to outside organisations.

Signed :

Chapter 1

1.0 Introduction

Personal Description

My name is Philip Taylor, I work as a controls engineer in the HVAC industry for a company called Building Services Controls based in Fforestfach in Swansea. One day a week I am giving day release to attend Swansea Metropolitan university (University of Wales Trinity Saint Davids) to study Electrical and Electronics Engineering part time (B-Eng).

Electrical and Electronics is something I've always had a keen interest in, from a young age I wanted to be an electrician and when leaving school I obtained my apprenticeship qualifications in electrical installation and maintenance. On joining my current company building services controls my Manager Andy Gill was keen for me to further my education, I then enrolled into Neath college to study Electrical and Electronics at foundation degree level. After completion of the Foundation Degree, the next step was to top up my qualification and complete my degree. I have thoroughly enjoyed studying at UWTSD and lucky enough to have met some great people. All the lecturers have been fantastic and extremely helpful. In particular Dr Gary Jones and Gareth Jones who create a relaxed learning environment which is important to part time students who usually have other commitments such as work and family, so when we do arrive to study our lecturers deliver the lectures in a good studying environment.

1.1 About Building Services Controls and current job role.

Since 1996, Building Services Controls Ltd has provided control solutions to the commercial industry for both, new construction and specific projects, throughout Wales and the UK and we have more recently expanded our operations to the luxury residential market.

Our client base crosses both public and private sectors and we offer systems to meet all needs, from the most basic requirements, to the state of the art solutions that today's modern building demands. Our reputation has been established over the years, not only for our solutions but for the service we provide. BSC prides itself on working closely with designers, contractors and end users alike and are available to advice and support at each stage of the implementation process.

We have been involved in some of the most prestigious buildings that have been constructed in South Wales, in many instances, providing high end technical solutions that assist towards the accreditation of BREEAM points in the pursuit of BREEAM excellence.

Our aim is to provide good quality, turnkey solutions, coupled with excellent customer service in the pursuit of delivering buildings to our clients that meet the ever increasing need for energy efficiency.

I am currently part of the engineering team within building services controls, my current role is a maintenance engineer/ commissioning engineer. I am keen to learn and the next step for me would be to become competent in the construction of control software. With the help of other engineers and self-learning and of course all the knowledge gained from B-Eng in electrical and electronics I hope to become a fully-fledged software engineer.

1.2 Introduction to the project

This project is mainly about temperature control, using a temperature sensor and microcontroller to control the speed of a small motor. According to the ambient surrounding temperature, using the concept of Pulse Width Modulation (PWM). Also being interfaced will be an LCD screen showing the temperature of the room and the PWM output to the motor.

The temperature controlled circuit will automatically control the fan speed in relation to the surrounding temperature. The program will be in CCs-C. After research is complete, the main components will be,

- Pic Micro Controller
- Temperature Sensor
- LCD Screen
- Small Motor
- Selection of circuit components likely to be;
- Capacitors
- Resistors
- Voltage regulator
- Transistor
- Power Switch

1.3 Project Aims and Objectives

The aim of this temperature controlled fan project is to successfully design and implement the fan using a temperature input which is then converted for a PWM output. As the temperature increases the fan speed increases through the PWM output. The ideal scenario for this project are for it to be installed into hardware such as computers or other components with electronics installed that require some form of cooling to prevent damage to the electronics. Also by incorporating the LCD screen it could help end users monitor the temperatures of the hardware components.

The main objectives are to have a full understanding of temperature control and PWM motor control, using a dc motor. Ideally by gaining this knowledge and further improving the project possibly creating other projects that are further advanced with more technology involved.

By creating a Gant and sticking to the deadlines and dates as best possible the project should run smoothly and knowledge should be gained. At the hand in date, a fully operational system is the desired objective and a full understanding of PWM output through temperature control using a micro controller and CCS code.

1.4 Project Gant Chart

A Gantt chart is a type of graph or planner which is adapted to suit your project deadlines from start to finish, in this project Gantt chart it has many key elements. One of the main elements being research, this is so important as it allows you to create the foundation of a successful project hence why so much time is usually spent on researching theories and ideas.

As it stands this is a realistic chart with deadlines that have been met and stuck to. Although research you could say was on going till the very end of the report. A lot of time was also spent on the design as ideas and different methods of reaching a final goal changed as the project was adapting. That said, implementation and software was also time consuming and at times stressful!

The main aim of the Gant chart is for the project to have deadlines and set goals to help the structure and development of the project stay on track. As this is an engineering project is acceptable for deadlines and to change as the project can change slightly or adapt through further research. It is safe to say that this project certainly changed as time went on and stress levels certainly fluctuated.

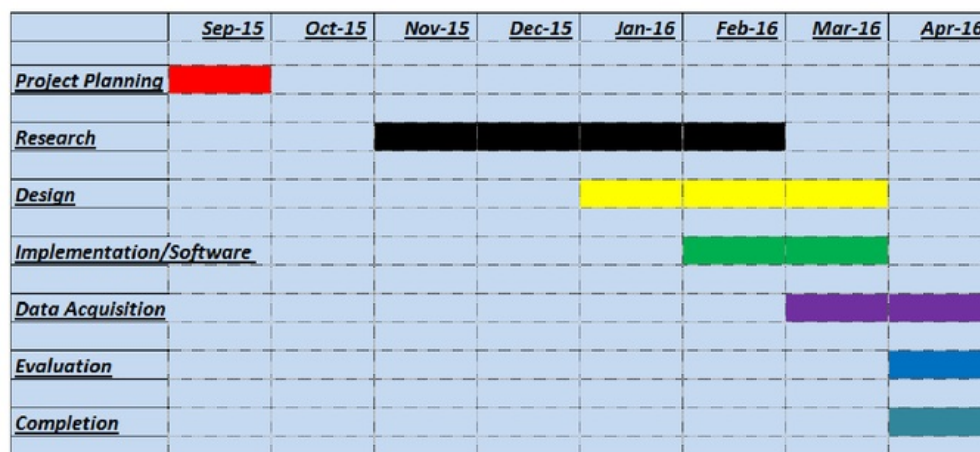


Figure 1 Gantt chart

2.0 Chapter 2 Research

2.1 Research

As research plays a considerable role in the construction of a major project it is vital that the correct research is carried out. As this project is based around electrical and electronic engineering making sure the correct literature and format of information required to successfully completing the written report and working prototype to a sound standard is critical.

2.2 Research Onion

Below is the “research onion”. The research onion is an essential tool when it comes to research, its steps and different layers can help guide and lead to the information and resources required. With its layers it has structure.

- Layer 1 - Research philosophies can differ on the goals of research and on the best way that might be used to achieve these goals.
- Layer 2 – Approaches.

Type 1 – Deductive. This approach is best suited to contexts where the research project is concerned with examining whether the observed phenomena fit with expectation based upon previous research. The deductive approach thus might be considered particularly suited to the positivist approach, which permits the formulation of hypotheses and the statistical testing of expected results to an accepted level of probability.

Type 2 – Inductive. This method is more commonly used in qualitative research, where the absence of a theory informing the research process may be of benefit by reducing the potential for researcher bias in the data collection stage. Interviews are carried out concerning specific phenomena and then the data may be examined for patterns between respondents. However,

this approach may also be used effectively within positivist methodologies, where the data is analyzed first and significant patterns are used to inform the generation of results.

- Layer 3 - Strategy. Here the onion looks at different strategies to build the foundations of the research, looking at action research case studies and archival research also looking at many different theories and surveys to give more depth to the research quality.
- Layer 4 – Choices Here Different methodology is looked at, Mixed, Mono and multi.
- Layer 5 – Time Horizons, this is extremely important as it can guide you through setting goals and deadlines. This is also important especially being an engineer as deadlines are expected to be met and met to a good standard.
- Layer 6 – Techniques and Procedures. This is the most important layer of the onion, this is where the data is collected and analysed.

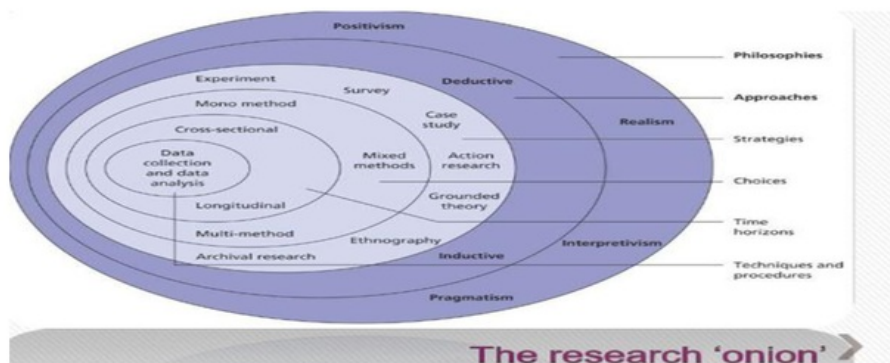


Figure 2 Research Onion

2.3 Research methodology

“Methodology” implies more than simply the methods you intend to use to collect data. It is often necessary to include a consideration of the concepts and theories which underlie the methods. For instance, if you intend to highlight a specific feature of a sociological theory or test an algorithm for some aspect of information retrieval, or test the validity of a particular system, you have to show that you understand the underlying concepts of the methodology.

2.4 Market Research Methodology

Market research is the process of collecting valuable information to help you find out if there is a market for your proposed product or service. The information gathered from market research helps budding entrepreneurs make wise and profitable business decisions.

The key to any successful business is to understand what it is that your customers want and giving this to them in a way that is profitable for you.

In order to find out what exactly it is that your customers want you must undertake a process called ‘Market Research’. This module will give you a basic understanding of the concept of market research, its various uses and provide guidance on how you can design your own market research questionnaire for your mini-company

2.5 Customer Targets

The cooling fan could be used in many different applications, it could be aimed at the computer or technology industries to help cool hardware such as drives and it equipment.



Figure 3 Customer Targets

Instead of the fan running at a set speed throughout with this design the speed of the fan would increase as the temperature increases, further improving the temperature environment for components.

Also the engineering /aerospace industry to help cool inverter drives or be installed into control panels to help dissipate heat and help maintain an appropriate working temperature for components. In truth, this project is aimed in general at every industry where cooling or where it is important to maintain a certain temperature. Even at office workers where they could require a fan to keep them cool and comfortable throughout the working day.

2.6 Market Research

2.7 Arctic Cooling F8 Pro TC 80mm Temperature Controlled Fan



Figure 4 Market Research

£9.99

Main features

- Temperature sensor on a 40cm long cable
- Accurate case temperature detection
- Cable can be positioned in wherever necessary
- Extremely quiet - only 0.3 Sone
- Patented fan holder eliminates the buzzing sound
- Patented vibration absorption

Cutting-edge thermal management concept

Unlike other generic temperature controlled case fans, the ARCTIC F Pro TC fan provides cooling according to not only the temperature, but also the overall necessity for cooling.

The revolutionary programmed temperature controller plays a key role. As shown in the chart, when case ambient air temperature is at safe level 0°C to 32°C, the ARCTIC F Pro TC fan speed remains at its lowest (500 rpm). This is to offer adequate ventilation at the lowest noise level possible. The

ARCTIC F Pro TC is therefore completely inaudible (0.05 sone) at low temperatures – a much quieter level than generic TC fans.

However, once a gaming system is at load, the case ambient air temperature will go up speedily, and without any case fans, most likely it will rise above 40°C, an overheated level for most PC cases. High performance and instant cooling is vital at this stage in order to eliminate the risk of overheating and system instability.

The ARCTIC F Pro TC is programmed to achieve top fan speed at 38°C. The fan responds to the rise in temperature swiftly – within a critical 6°C range, the rpm of the ARCTIC F Pro TC fan increases from around 500 to its maximum of 2,000 rpm (the steep curve in the chart). Heat is dissipated from the case rapidly in order to achieve immediate cooling. As a result, the case air temperature remains at 38°C or below and thus the possibility of having a system failure can be eliminated.

Highly flexible – sensor on a 40cm cable

The accurate temperature sensor of the ARCTIC F Pro TC is equipped at the end of a 40cm cable. This gives much better flexibility when choosing the most appropriate spot that users would like to have the temperature detection.

2.8 Vktech Cooling Air Fan Auto Vehicle Truck DC 12V Cooler Speed Adjustable



Figure 5 Market Research

£36.99

Product Description

Features:

Brand new and high quality

Low energy consumption, low noise.

Cage shape design, makes the wind more cool!

Portable and easy taking, good looking.

The cigarette-lighter plug allows you to power it from your vehicle lighter socket.

Specifications:

Input power: 12V DC

High / Low / Off rotating switch

Noise Level: <45db

2.9 LCD CD Panel 2 Channel Fan Speed Controller & CPU Temperature with Sensor + Two(2) USB

Figure 6 Market Research

£49.99

Description:

2 port USB 3.0 2 channel fan controller with LCD screen, 2 channel temperature display, 2 fan speed display. This is a 2 knobs fan speed controller. It can control 2 channel fans in same time. When the computer of temperature exceeds 60 degrees and when the fan stuck or is abnormal , the temperature icon displays and alarms.

- 2 channel fan controller come with lcd screen
- LCD Display
- 2*USB3.0 HUB Interface,compatible usb 2.0/1.1

- Plug and Play 2 port usb 3.0 and transmission speed is up to 5Gbps.
- 5.25 inch driver bay
- Output voltage: 5v-12v
- Digits Size : 15 x 7.8 x 4.2cm/ 5.9" x 3" x 1.6" (L*W*H)
- Input voltage: 5v and 12v
- Maximum power: 10w
- Size: 14.9*7.8*4.2 cm

2.10 Ram Air-Pro Fan Controller



Figure 7Market Research

£169.99

Ram AIR-PRO - Combined Temperature and Fan Speed Controller

The AIR-PRO has two plug points, one for an intake fan and one for an exhaust fan. Each plug point can control fans up to a maximum power of 320 watts, which is approximately 1.4 amps each. The controls and features enable the use of two fans of the same air flow rate, whilst still being able to reduce the speed of the intake!

Controls and features include:

Idle Speed Control Knob

This controls the minimum speed that both fans will attain. This happens when the air temperature falls below your chosen temperature setting.

Balance Control Knob

This control adjusts the differential between the intake fan and exhaust fan. This is in order to maintain the correct balance of intake to extraction when using similarly sized and rated fans. When

this knob is turned all the way anti-clockwise (0%), there will be no difference between the two fan speeds. When the control is turned all the way clockwise (100%), the extraction fan will run at twice the speed of the intake fan. This means that an effective negative pressure can be obtained and easily adjusted at any time.

Temperature Control Knob

This knob is simply used to set the desired growroom temperature from 5 to 45 degrees. When the knob is being operated, the digital numerical display will show the required temperature with a small dot at the right hand side.

Digital Numerical Display

When temperature is being set or adjusted, the digital numerical display will show the target temperature. When adjustment is completed and the control is no longer being moved, it will display the actual temperature measured by the temp sensor. When the actual room temperature rises higher than the user's pre-set desired temperature and the fan controller is trying to cool the room, the numerical display will flash while displaying the actual room temperature.

Finally, if there is a fault or failure with the temp sensor, the digital numerical display will be blank apart from two small dots (bottom left and bottom right). In this case, the controller will default the fan speed to 50%, whilst maintaining a differential between the intake and exhaust fans.

LED Indicator

When the controller is effectively maintaining and controlling the temperature, this LED light will be constantly on. When the room temperature is lower than the user's pre-set desired temperature this LED will flash.

Reset Button

This is a simple circuit breaker that will trip to protect the controller should it ever overload. If

tripped, simply disconnect the unit from the main power and press the reset button and the controller will be ready to use again.

2.11 Market Research Evaluation

Device	Size within set standard?	LCD	Operating parameters match the PIC?	Price
RAM AIR PRO	NO	NO	NO	£169.99
2 CHANNEL LCD	YES	YES	NO	£49.99
VKTECH	NO	NO	NO	£36.99
ARTIC COOLING	NO	NO	NO	£9.99

From the market research carried out it is clear there are no other devices on the market similar to this proposal and therefore it could be a good idea to explore this further.

Market research is an important tool in creating a new project. It gives you an insight into the types of similar devices and price ranges on the market, where you think your product can make an impact and what markets to avoid.

Market research involves gathering data and analysis information for the specific market your intending in entering. Looking at present ideas prices and even ideas from the past which can help in designing your project. You can look into where the product was successful around the world, look at customers spending habits and then decide on a location to best promote your project or if you think it can make an impact on the market worldwide.

It is important to research the accurate information taking in account the competition, target audience, and the industry in general. It allows you to gauge how feasible the project really is before committing to it.

Market research provides opportunities to avoid making mistakes and can help overcome current market issues and challenges.

Market research contains to main pieces of strategy which are primary and secondary information.

Primary Information

- This is research you accumulate personally or gain help from someone to help you gain the research.
- **Secondary information**

This is the research that already exists and is done for you, these include studies and reports compiled by other people, agencies etc. 90% of the information gathered is secondary market research.

2.12 Market Research Survey

Question 1

A quick online survey was created to understand if the project could make an impact on certain markets if this prototype could be devolved further in the future. Below are multi choice questions aimed at family and friends in order to see how often issues such as overheating occur and if certain devices could benefit them in protecting devices such as play stations and computers etc.

Question 1

This question is just a basic question, do they own consoles laptops etc.

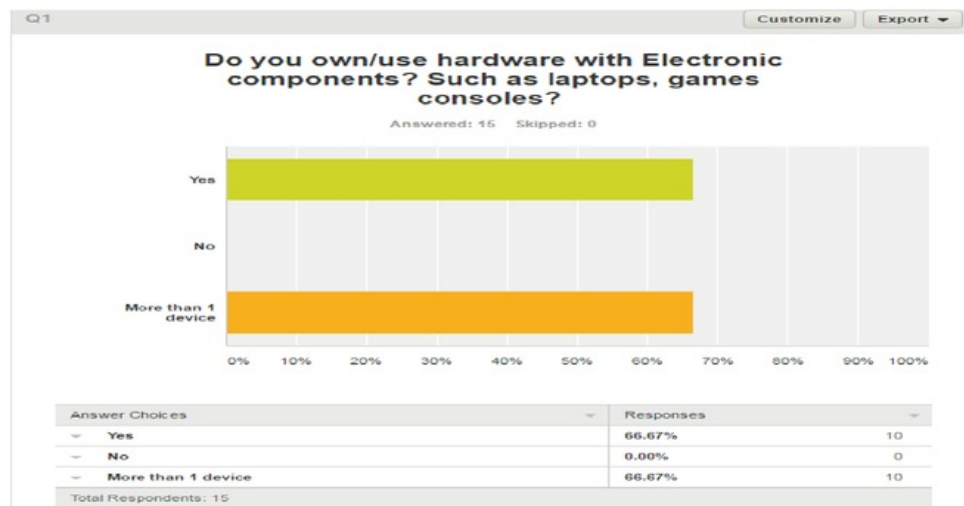


Figure 8 Survey Q1

Above asking whether the person/persons owns hardware where this project could be utilised. The feedback was a success with the graph above proving this.

Question 2

This question is just trying to find out if overheating has occurred in their devices before?

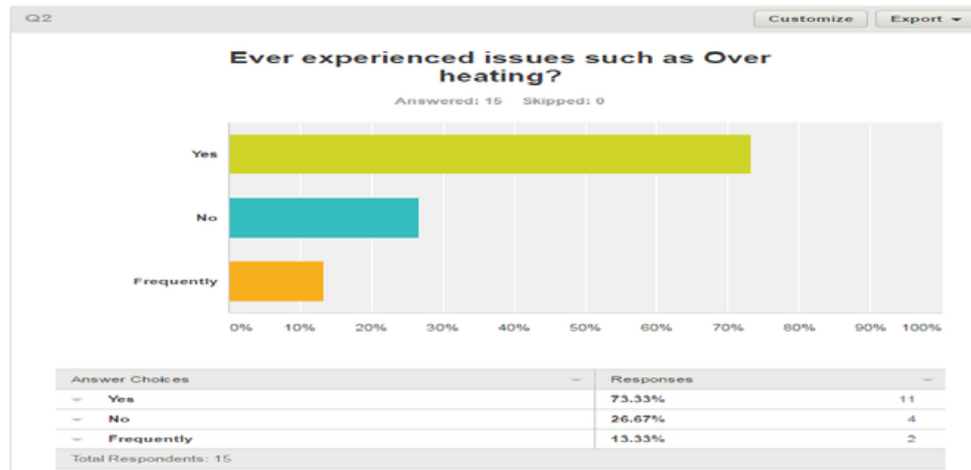


Figure 9 Survey Q2

As seen above that most users have over heating issues, probably caused by dust or poor ventilation to and from the unit.

Question 3

This question is just to find out if people believe their device could benefit from the aid of cooling.

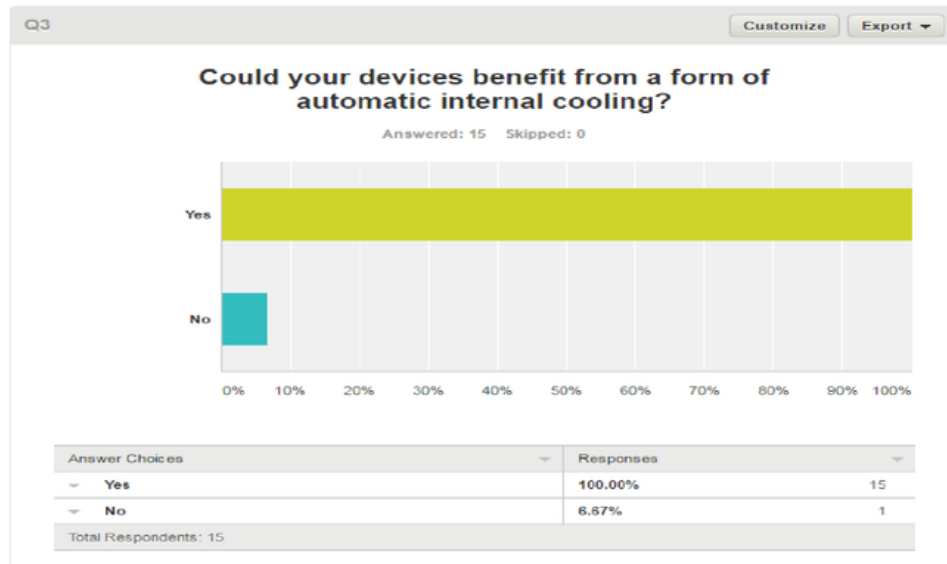


Figure 10 Survey Question 3

A successful question as mostly everyone said they could benefit from the device created in this project.

Question 4

This is an important part of the survey, as no products show internal temperatures or warn the end users of overheating. By visually displaying the temperature it could dramatically improve the end users awareness of protecting their device from overheating.

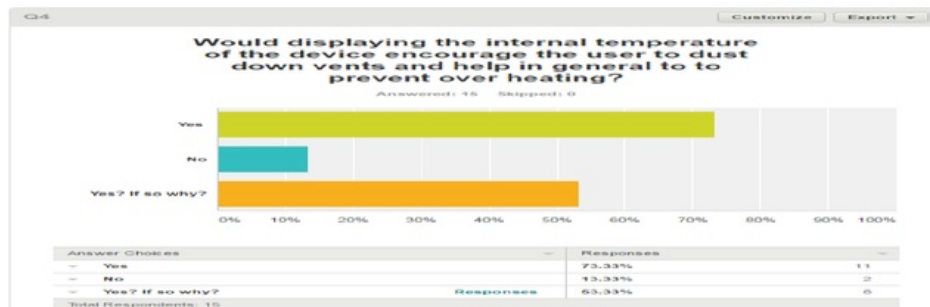


Figure 11 Survey Q4

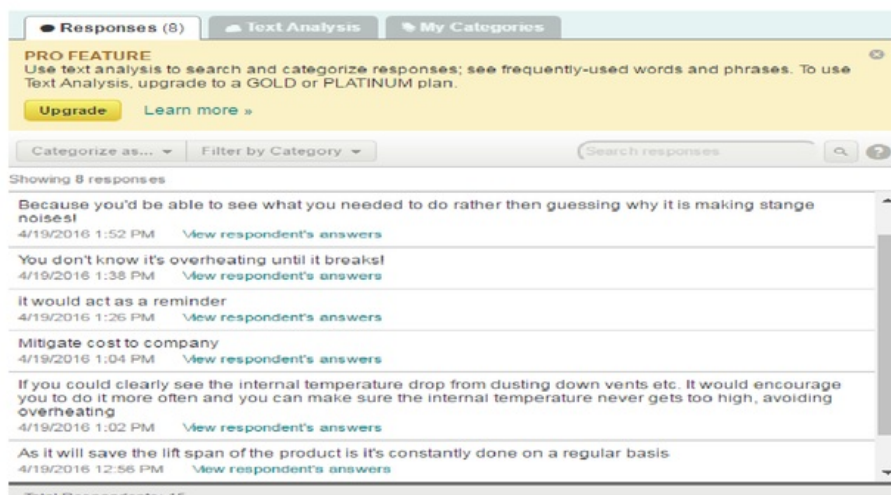


Figure 12 Survey Q4 Responses

From the responses is clear displaying internal device temperatures could help end users position clean and automatically further improve the life span of the device.

Question 5

This question is to find out how much people are willing to pay for such a automated cooling system.

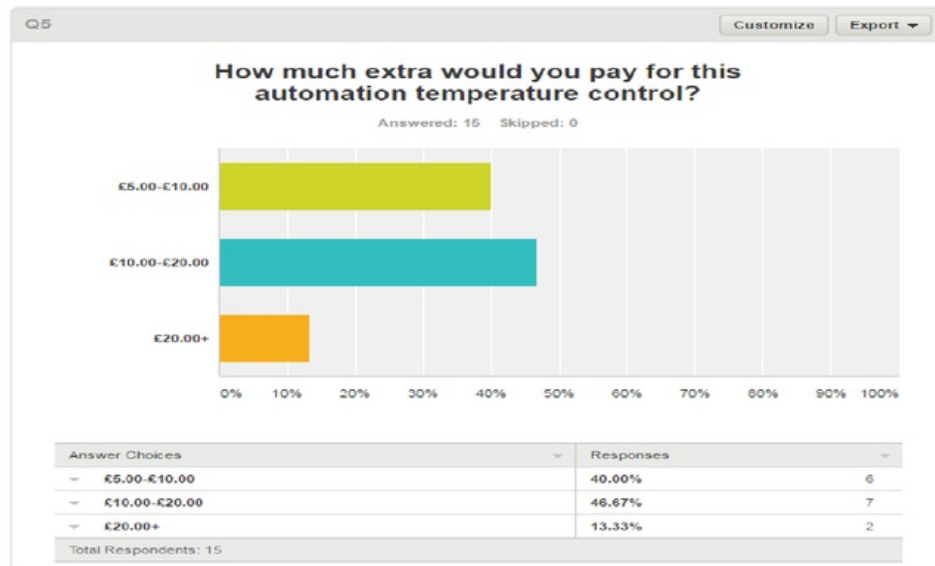


Figure 13 Survey Q5

By viewing these results it could help pitch the price.

Question 6

This question is just asking do they believe such a device could improve their product and raise awareness of potential over heating within the device.

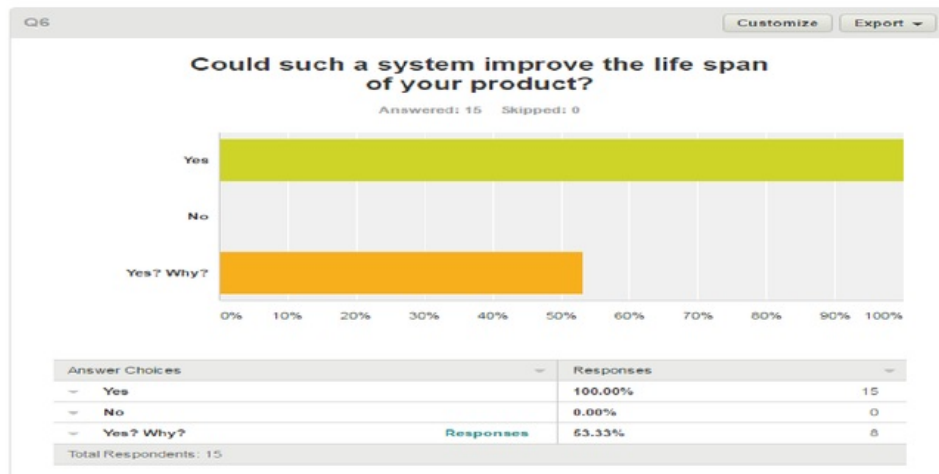


Figure 14 Survey Q6

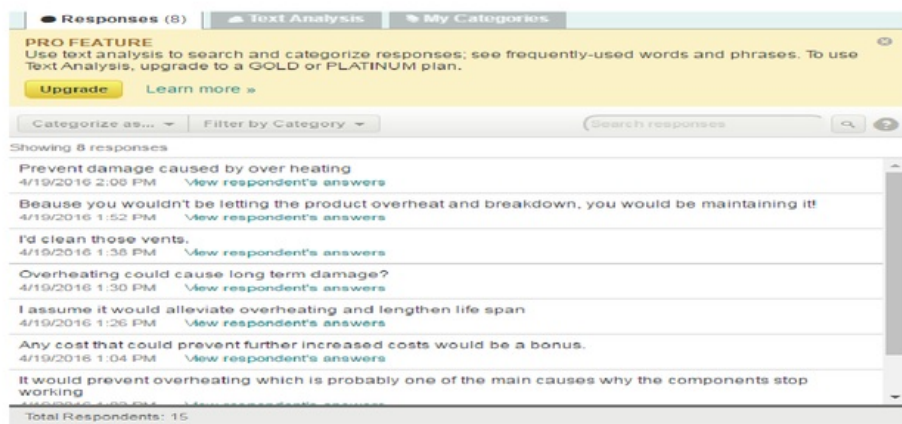


Figure 15 Survey Q6 Responses

From the responses users think they could benefit from such a device.

2.12 Market Research Conclusion

From the market research gathered and from feedback from the survey, there is most certainly an area in the market where such a device where internal temperature of a device could be implemented. Currently no devices display internal temperature, if this was the case then end users would be encouraged to clean, avoid putting them in certain areas and make sure airways are clear to avoid heat buildup and increasing the chances of overheating occurring. This could potentially cost end users £200-400 in purchasing products.

2.13 Temperature Sensor Research

When considering temperature sensors, there are different types to choose from. Things to consider are its application and what temperature range it will be measuring. Also it could be worth considering the environment it will be installed into, will it be in an enclosure of some sort or in the open measuring ambient temperature or in water?

This is important when it comes to final selection of the sensor, as things like costing budgets and safety need to be considered before purchasing the equipment.

2.14 Thermocouples

The thermocouple is the most commonly used sensor, it is relatively cheap, durable and can be used in long distance wiring. They are also self-powered with different types to measure at a specific range.

An important use of the thermocouple is their non-linearity when the output voltage is in relation to temperature.

Thermocouples are made of two pieces of metals joined together at one end then separated at the other. They work on the principle that the thermoelectric effect with the two metals producing a voltage when there is a difference in temperature between the two metals. As temperature rises the voltage output rises and likewise when the voltage decreases.

Advantages

- Self-Powered
- Durable and extremely reliable
- Wide range of temperature measurement

Disadvantages

- Non Linear and need a cold junction for compensation
- Low voltage signals making it difficult to eliminate surrounding noise
- Only accurate when the correct cabling is used.

2.15 Thermistors

Alternative to the thermocouple is the temperature sensor thermistor. These work by sensing the change in resistance as the temperature either decreases or increases. It has high sensitivity meaning it will change appropriately in accordance to the surrounding temperature.

The principle of a thermistor is that when resistance is decreasing it usually means the temperature has increased. When used in control systems they usually require a correction of some sort to establish the correct reading.

There is an equation which links temperature and resistance called the Stein-Hart equation.

Advantages

- Simple to operate – using two wires to wire the sensor
- Quick Response times
- Small in size
- Respond quickly to temperature change

Disadvantages

- Smaller Measuring Ranges
- Not very durable
- Possible calibration issues
- Require current for excitation

2.16 Motor Research

When looking to choose a motor for this project the main motors of choice were AC or DC motors.

Although it is normally a matter of personal preference when it comes to selection of motors sensors and circuit components some parameters and applications need to be considered.

As the requirement was to control the speed of a motor both AC and DC motors were suitable as they both have the capacity to do this.

AC motors or drives use frequency change in the electrical supply of the motor to generate the speed of the motor. Where-as DC motors are driven at a speed in proportion to the voltage functional to it.

Advantages of Ac motors

- Concentrated power line disruption
- Lower power consumption on start up
- Controlled speeding up
- Manageable start up current
- Adjustable operation speed (Frequency)
- Adjustable torque

Disadvantages of Ac motors

- Complicated to commission
- Complicated to operate due to amount of parameters
- PLC interface required
- Put pressure on the end users technical knowledge

Advantages of DC Motors

- High start up torque
- Easily installed
- Wide range of speed control
- Quick starting/stopping, reversing/accelerating
- Easy to find/buy
- Great for small projects

Disadvantages of DC motors

- Hazardous and Explosive
- High maintenance costs
- High maintenance required

2.17 Control Research

For this project a DC motor and speed control is required. Using as temperature sensor as the input and then controlling the speed of the motor through the PIC. Now a days most often AC motors are used in speed control of motors but as this is a small electronics project a DC motor is more suitable as it is a small DC power controlled project.

2.18 How to control fan speed

There are many methods to controlling the speed of a motor here are a few.

Variable Power Excitation

With the help of voltage regulators varying the speed of a DC motor can be achieved through varying the voltage. Voltage regulators regulate the voltage within certain ranges, depending on Dc motor

ratings. Power supplies that make with voltage regulators do not have high power capability. So this method isn't used frequently.

Pulse Width Modulation

This method controls the output voltage from a micro controller with continuous frequency switching, also by adjusting the time of switching. For this project, within certain temperature ranges a PWM output would be generated and control the motor speed

Below is the illustration of duty cycles.

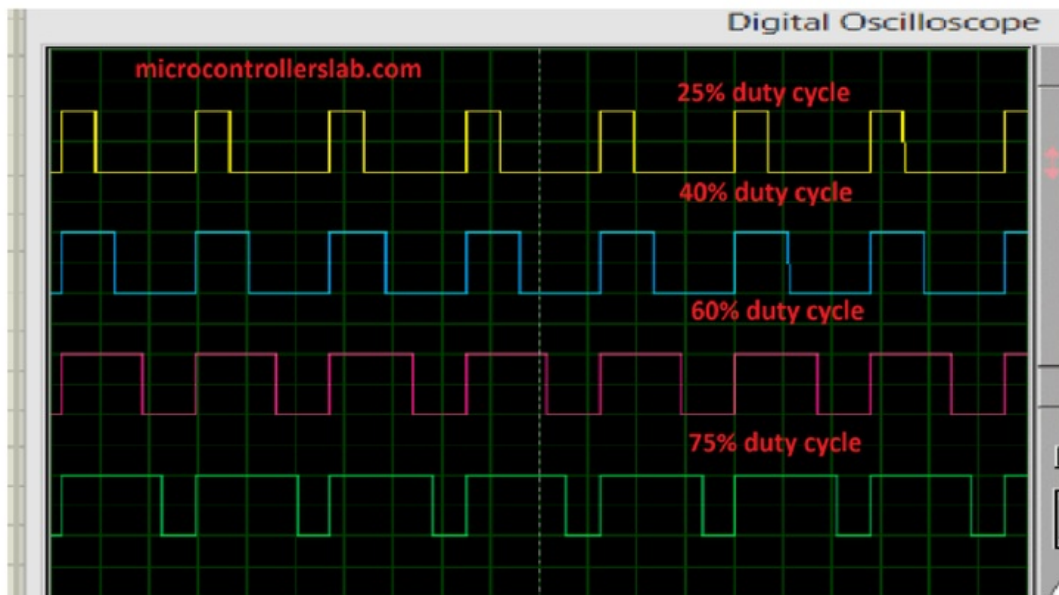


Figure 16 PWM

2.19 Sensor Research

2.20 Temperature Sensor, RS Pro TT911/10K3A1, Interior Room, Thermistor



Figure 17 Sensor 1

£10.99

Temperature Sensor

Thermistor and Pt100 type sensors in a variety of packages suitable for use with most air conditioning control systems.

Sensor Types:

Thermistor: direct thermistor (NTC) temperature (10k Ω at 25°C) versions. These are degradable components and should be replaced on a 2-3 year cycle.

Pt100 sensor: 2 wire sensors with brass probes providing a linear response and positive temperature coefficient

This temperature sensor would be ideal choice for selection, as it is a ambient room temperature sensor it would accurately read temperatures within the parameters set within the program. Also with it being within the power supply range of the pic no external supply would be required. It could as be placed outside and accurately read the temperature although its packaging wouldn't be suitable.

2.21 DS18B20 1-Wire Digital Thermometer Sensor



Figure 18 Sensor 2

£04.99

Main Features

DS18B20 1-Wire Digital Thermometer Sensor

- A wide ranging temperature sensor for data logging and temperature control projects
- Very popular device with Arduino, Raspberry Pi and general electronic applications
- Unique 1-Wire interface requires only one port pin for communication
- Each device has a unique 64-bit serial code stored in an onboard ROM
- Multidrop capability simplifies distributed temperature sensing applications
- Fully integrated, requires no external components
- Low power supply range 3.0V to 5.5V and can be powered using data line
- Wide range, from -55°C to $+125^{\circ}\text{C}$ (-67°F to $+257^{\circ}\text{F}$)
- Accurate reading, only $\pm 0.5^{\circ}\text{C}$ accuracy from -10°C to $+85^{\circ}\text{C}$
- User selectable thermometer resolution from 9 to 12 bits
- Fast response, converts temperature to 12-bit digital word in 750ms
- User-definable non-volatile alarm function settings

PIN CONFIGURATIONS

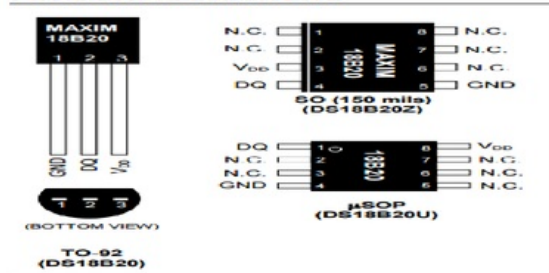


Fig 13

This is an extremely popular industry standard thermometer sensor device. It is widely used across the electronic industry to develop temperature based projects. Its usual applications would be weather stations, room control, industrial systems. Its features would be within the parameters required and would accurate in reading temperature to 0.5°.

2.22 HONEYWELL S&C HEL-705-T-0-12-00 RTD Sensor, Platinum, 100 ohm, -200 °C, +260 °C, HEL-700 Series



Figure 19 Sensor 3

Fig

£22.99

Features

- Wide temperature range
- Interchangeable
- Accurate
- Fast response time
- Laser trimmed
- Ceramic case
- TFE Teflon® or fibreglass leadwires
- Ready-to-use and fully assembled elements
- 28 gauge, nickel-coated stranded copper, Teflon insulated termination material
- 50MR at 50VDC, 25°C insulation resistance

Product description

The HEL-705-T-0-12-00 is a thin film Platinum RTDs (Resistance Temperature Detector) is designed to monitor or control critical temperatures in industrial applications. It provides a linear change in resistance versus temperature, combining high linearity, stability, accuracy and wide temperature range in a small. The HEL-705-T-0-12-00 is designed to measure temperatures from -75 to 540°C (-100 to 1000°F) with high accuracy. These fully-assembled elements are ready-to-use in probe assemblies, without the need for fragile splices to extension leads. This products is manufactured using a thin layer of platinum deposited on an alumina substrate and are laser trimmed to a resistance interchangeability of a standard $\pm 0.2\%$ ($\pm 0.5^\circ\text{C}$ accuracy). The sensor chip is then glassed, wired and potted or ceramic fired to result in a cylindrical alumina package with either TFE Teflon® or fibreglass, insulated lead wires.

With all these features and great specification the price difference between this product and others chosen for research is a possible stumbling block. In saying that most of its features and specifications are great.

2.23 LM35 Linker Temperature Sensor



Figure 20 Sensor 5

Fig

£5.99

Linker Temperature Sensor

- Simple to connect temperature sensor
- Create your own weather station and more!
- Connects directly to GPIO Pins

Product Description

Thermal Module is a temperature sensor consists of one LM35, LM35 is a temperature sensor which has been widely used, because it uses internal compensation, so the output can begin with zero. At room temperature, the LM35 requires no additional calibration process can reach $\pm 1/4$ degree of accuracy. The power supply mode has single power supply and the positive and negative dual power. The mode of the positive and negative dual power can provide negative temperature measurement. The LM35 temperature sensor output voltage has a linear relation with the Celsius temperature. 0 degree output 0V increased by 1 degree, the output voltage increases 10mV.

2.24 Siemens QAA 24 Room Temperature Sensor



Figure 21 Sensor 6

£74.99

Product details

Siemens Qaa 24 Room Temperature Sensor

The sensors for flush mounting are used in heating, ventilation, and air conditioning plants to acquiring the room temperature. They are also available with KNX.

They can also be used as a controller for room temperature or ventilation or to control lighting and blinds. The current status of the air quality can be displayed on a three-color LED display.

Range of use:

- Temperature: 0...50 °C
- Supply: DC 15...36 V
- Output: DC 0...5 V / DC 0...10 V / DC 0...20 mA /

DC 4...20 mA / DC (0)/4...20 mA

Siemens are a well-respected company with worldwide recognition, their products are renowned for their quality and value for money. But in this instance it is hard to justify choosing this sensor for not only the price but for the specifications. It would mean further complicating the circuit to make this sensor suitable. A full comparison of all sensors is to follow.

2.25 Motor Research

2.26 1.5-3V Small Motor



Figure 22 Motor 1

£03.49

Product details

1.5-3V Small Motor

- Small motor flattened at top and bottom for easy mounting
- Great for hobbies, modelling, R&D, and educational use
- Operating voltage between 1.5V and 3V
- Up to 6990 rotations per minute
- Creates torque up to 6 gf.cm
- Compact size to fit small projects

What size is this motor?

This motor is compact and ideal for use in small projects. The top and bottom are flattened to make it easier to mount. The motor is capable of rotary speeds up to 6990 rpm.

This motor is an ideal component for this project, its supply voltage specifications mean it can be directly powered from the pic via the PWM output pin. Meaning no external power supply is required to start excitation. Also its current rating is with the Pic 16f877 parameters.

2.27 MFA 1.5-3V Small 100:1 Single Ratio Motor Gearbox



Figure 23 Motor 3

£24.99

Product Details

- Small motor with integral gearbox
- Great for hobbies, modelling, R&D, education and even smaller industrial use
- Operating voltage between 1.5V and 3V
- Rotations per minute of up to 92
- Creates torque up to 1000 gf.cm (0.098 Nm)
- Compact size to fit even small projects

Specifications

This small metal motor with its built-in gearbox is ideal for projects and applications where space is at a premium. The built-in gearbox can increase your turning power (torque) at reduced rotations per minute from the motor. The optimum ratio for this will depend on your project. Designed to fit into a range of hobbies modelling, R&D, educational and even small scale industrial projects and products. This solidly constructed steel and brass motor is mounted on a 1mm thick steel bracket to prevent movement while it's working. The motor and gearbox incorporates a high quality three pole motor with sintered bronze bearings and has a 4 mm diameter central output shaft.

2.28 3V Hobby Motor 6600 RPM w/ Gear



Figure 24 Motor 4

£6.99

Product Details

- The motor has a voltage range of 1.0 to 3.0VDC
- It works well for basic things
- Rotation : clockwise from the motor shaft

Specifications

This is the new 3V Hobby Motor 6600 RPM with Gear now with a 6mm, 10 tooth, gear to make your basic projects a little simpler to manage.

Rated Voltage: 3.0VDC Voltage

This motors specifications are well within the specified parameters and would work well directly powered from PWM output from the pic

2.29 MFA 1.5-3V Small 12200 rpm motor



Figure 25 Motor 5

£6.99

Product Details

MFA 1.5-3V Small 12200 rpm motor

- Small motor with removable bracket
- Can be used to power a wide range of experiments, projects, hobbies and models
- Operating voltage between 1.5V and 3V
- Rotations per minute of up to 12,200 rpm
- Creates torque of up to 13gf.cm
- Compact size to fit small sized projects

What size is this motor?

This three-pole motor is ideal for small projects with its compact 38mm (29.3mm not including shaft) length and 21mm diameter. Weighing just 20g the motor is perfect for portable models. Capable of producing up to 12,200 rotations per minute and torque of up to 13gf.cm (gram-force cm). Comes with its own bracket for easy mounting and can run in either direction by reversing the polarity of the input voltage. This motor operates on 1.5 to 3 volts and has a central 2mm output shaft.

2.30 Battery Research



Figure 26 Battery

£1.99

Technical Specification

SKU	DUR-AB-01336
Manufacturer Part Number	MN1604B1PLUS+++
EAN Code	5000394019256
Weight (g)	55
Units per box/card	1
Voltage	9V
Dimensions	Height: 48.8mm Width: 26mm Depth: 16.9mm
Item Codes	9V, 6LR61, MN1604, 6LR1, PC1604, 1604LC, K9V, 6AM-6, 4022, 6AM6, E-BLOCK
Uses	Microphones, Smoke Alarms
Chemistry	Alkaline

These features are perfect for the project and are also ideal when using radios, transmitter and wireless microphones. When connected in line with 5v regulator.

2.31 Components List

Cost Table		
Components	Cost	Quantity
Microchip	STORES	1
9V Battery	£1.99	1
Temperature Sensor	£5.99	1
Motor	£3.49	1
Breadboard	STORES	1
Resistors 10 K / 230 Ohm	STORES	5
Cable Assorted colours	STORES	2Meters
Crystal	STORES	1
Green 5v LED	STORES	1
Transistor	STORES	1
Propellers for Motor	£6.99	Box of 6
LCD	STORES	1
Power Switch	STORES	1
Capacitors	STORES	5
5v Regulator	STORES	1
Total cost	£18.46	

2.32 Sensor Comparison

Sensor	Voltage supply within spec?	Cuurent rating within Spec?	Output	Price
SIEMENS	NO	NO	ANALOG	£74.99
LM 35	YES	YES	ANALOG	£5.99
HONEYWELL	NO	NO	ANALOG	£22.99
DIGITAL THERMISTOR	YES	YES	ANALOG	£04.99
INTERIOR ROOM THERMISTOR	YES	YES	ANALOG	£10.99

From the above temperature sensors the LM 35 has been chosen, it is within specification and features such as pin connections and its availability have made it the most suitable for project.

2.33 Motor Comparison

Motor	Voltage supply within spec?	Cuurent rating within Spec?	RPM	Price
MAPLINS 6990RPM	YES	YES	6990	£03.49
MFA 100:1	YES	NO	12000	£24.99
HOBBY MOTOR	YES	YES	6600	£06.99
MAPLINS 12200	YES	NO	12200	£06.99

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The Maplins 6990 was chosen, it is within the specifications required and reasonably prices and readily available.

3.0 Chapter 3

Design + Implementation

3.1 System Flow Charts

System operation

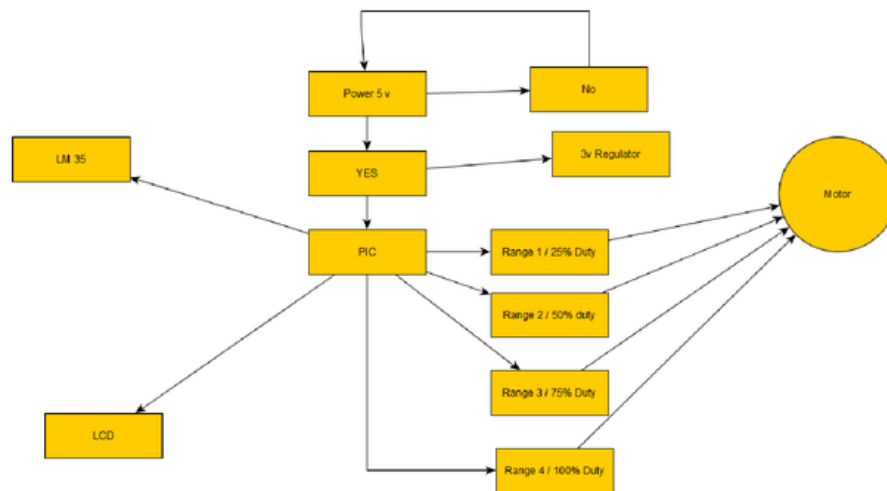


Figure 27 System Flow Chart

Here we have the system flow chart, When the 5v power supply has excited the pic the temperature is read and depending on the temperature range a PWM output is sent to the motor telling it what percentage duty needs to run it in correspondence to the temperature.

POWER

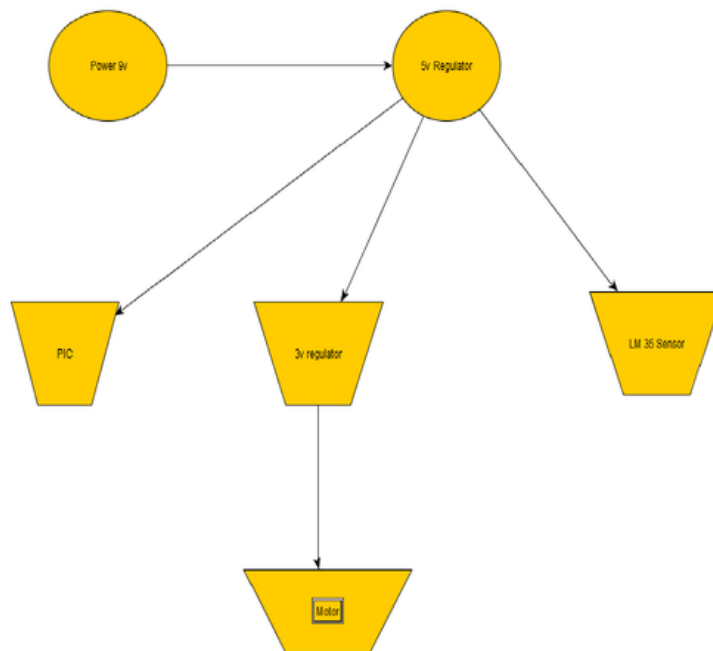


Figure 28 Power Flow Chart

Here is the system power flow chart showing where the power is coming from and where it is regulated and for what device

Hardware

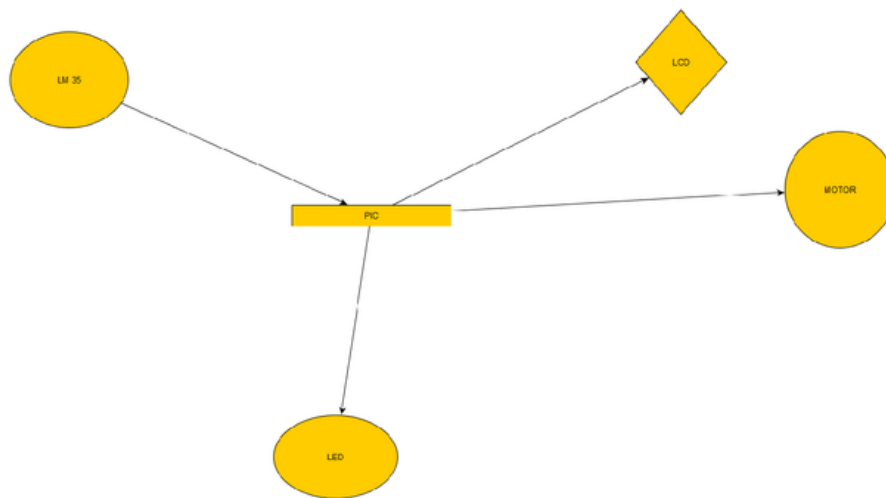


Figure 29 Hardware Flow Chart

Here are the systems main hardware components. With everything based around the micro controller.

Design Operation

3.2 System Control

The design stage of this project could only be completed once most of the research was complete and a clear method of how the project should work finalised. The circuit design was completed in Proteus, here using circuit components, temperature sensor, and virtual terminals and a Digital Oscilloscope. Through incorporating an LCD screen the end user can visually see the temperature value and with knowledge of operation should be able to understand what speed the motor should be running at. In the Proteus design to simulate the PWM output to the motor a 5v LED was used, depending on the duty would depend on how often the LED would flash.

<u>Temperature Range</u>	<u>Motor Duty %</u>	<u>PWM Output</u>
>=20 <=25	25%	31
>=26 <=30	50%	62
>=31 <=35	75%	93
>=36 <=40	90%	124
<=20 >=40	0%	0

Put simply,

- Between the temperature range of 20 and 25 degrees C the motor should operate to 25% Duty.
- Between the temperature range of 26 and 30 degrees C the motor should operate to 50% Duty.
- Between the temperature range of 31 and 35 degrees C the motor should operate to 75% Duty.
- Between the temperature range of 36 and 40 degrees C the motor should operate to 90% Duty.
- If the temperature is lower than 20 degrees or higher than 40 degrees the motor should not operate duty should be 0%.

This description of operations has to be implemented in the design software.

3.3 Micro Controller Specification

The operation of this project has certain requirements from the micro controller. The chosen Micro controller required capacity for Analogue inputs, Analogue to Digital conversion, Digital Output, PWM Output, and LCD capacity. The chosen Micro controller was a 16f877. Micro controller 16F877 was ideal for selection, it covered all the basis required to complete the project.

Product	Buy	Status	Documents	5K Pricing	Program Memory Size (Kbytes)	RAM (bytes)	EEPROM / HEF	Pin count	Max. CPU Speed MHz	Periphera Pin Select (PPS)
PIC10F000				[Reset]	[Reset]	[Reset]	[Reset]	[Reset]	[Reset]	[Reset]
PIC10F004				\$0.39	0.75	25	0	8	18	No
PIC10F008				\$0.48	1.5	64	0 / HEF	14	20	Yes
PIC10F013				\$0.48	1.75	67	128	18	32	
PIC10F014				\$0.62	3	68	132 / HEF	20	48	
PIC10F018				\$0.83	3.5	72	288	27		
PIC10F017				\$0.64	3.75	138	388 / HEF	28		
PIC10F048				\$0.85	7	134	84	38		
PIC10H040				\$0.57	14	182	84 / HEF	40		
PIC16F004				\$0.81	18	274		48		
PIC16F887	\$	In Production		\$1.78	14	368	256 / HEF	40	20	No

Figure 30 PIC SELECTION

3.4 Pic Research/Requirements

Pic 16F877/16F877A	 	Description
Correct I/O Required		• Temperature Sensor • LED
PWM Output		• Driving motor to a set duty
LCD Capacity		• Displaying Temperature Values
Analogue to Digital Converter		• Converting temperature value for the PWM output
Oscillator		• Crystal Used
Timer Capability		• For Software

PIC16F877

Pic 16f877 is an ideal micro controller for the project I will be completing. The main features that will benefit this project are the analogue input pin and the PWM output pin. The Analogue temperature will be converted by the analogue to digital converter and the PWM output will be driving a low powered motor directly using a transistor.



Figure 31 PIC 16F877

Pic 16f877 is a high performance pic, here are some of its features

Peripheral Features

- Two 8-bit timer/counter (TMR0, TMR2) with 8-bit programmable pre scalar
- One 16 bit timer/counter (TMR1)
- High current source/sink for direct LED drive
- Watchdog Timer (WDT) with Separate RC Oscillator
- Two Capture, Compare, PWM Modules
- Synchronous Serial Port with SPI and I²C
- Eight Channel, 10-bit Analog to Digital Converter
- Universal Synchronous Asynchronous Receiver Transmitter (USART)

Special Microcontroller Features

- Power-On Reset
- Power-up Timer (PWRT) and Oscillator Start-Up Timer (OST)

- 1,000 erase/write cycles Enhanced Flash Program Memory
- 1,000,000 typical erase/write cycles EEPROM Data Memory
- Selectable Oscillator Options

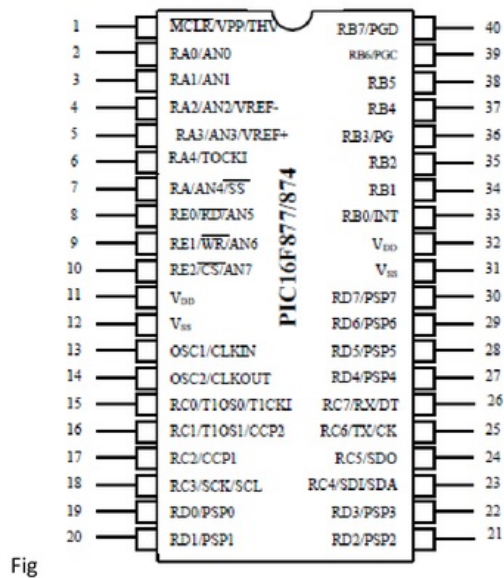
▶ CMOS Technology

- Low power, high speed CMOS FLASH technology
- Fully Static Design
- Low Power Consumption

▶ I/O and Packages

- 33 I/O pins with individual direction control
- 40-pin DIP

3.5 Pic Pin Layout



Fig

Figure 32 PIN LAYOUT

- This illustration helps us understand how the pic will be programmed and physically wired for the design and build stage of the project.

The pic has

- Data memory = 368 bytes
- Data memory(EPROM) = 256 bytes
- Interrupts = 14
- I/O = Ports A,B,C,D,E
- Timers = 3
- PWM Output = 2

3.6 Pic Pin Description

Pin Number	Description
1	MCLR/VPP - Master Clear Input
2	RA0/AN0 - Port A
3	RA1/AN1 - Port A
4	RA2/AN2/VREF-/CVREF - Port A
5	RA3/AN3/VREF+ - Port A
6	RA4/T0CKI/C1OUT - Port A
7	RA5/AN4/SS/C2OUT - Port A
8	RE0/RD/AN5 - Port E
9	RE1/WR/AN6 - Port E
10	RE2/CS/AN7 - Port E
11	Vdd - Positive Power Supply
12	Vss - Ground
13	OSC1/CLKI - Oscillator Input
14	OSC2/CLKO - Oscillator Output
15	RC0/T1OSO/T1CKI - Port C
16	RC1/T1OSI/CCP2 - Port C
17	RC2/CCP1 - Port C
18	RC3/SCK/SCL - Port C
19	RD0/PSP0 - Port D
20	RD1/PSP1 - Port D

20	RD1/PSP1 - Port D
21	RD2/PSP2 - Port D
22	RD3/PSP3 - Port D
23	RC4/SDI/SDA - Port C
24	RC5/SDO - Port C
25	RC6/TX/CK - Port C
26	RC7/RX/DT - Port C
27	RD4/PSP4 - Port D
28	RD5/PSP5 - Port D
29	RD6/PSP6 - Port D
30	RD7/PSP7 - Port D
31	Vss - Ground
32	Vdd - Positive Power Supply
33	RB0/INT - Port B
34	RB1 - Port B
35	RB2 - Port B
36	RB3/PGM - Port B
37	RB4 - Port B
38	RB5 - Port B
39	RB6/PGC - Port B
40	RB7/PGD - Port B

Figure 33PIN DESCRIPTION

Used Pins

13	OSC1/CLKIN	RB0/INT	= 23
14	OSC2/CLKOUT	RB1	= 24
		RB2	= 25
2	RA0/AN0	RB3/RCM	= 26
3	RA1/AN1	RB4	= 27
4	RA2/AN2/VREF-/CVREF	RB5	= 28
5	RA3/AN3/VREF+	RB6/PGC	= 29
6	RA4/T0CKI/CT0OUT	RB7/P6D	= 40
7	RA5/AN4/SS/CS0OUT		
		RC0/T1OSC/T1CKI	= 15
8	RE0/AN5/RD	RC1/T1OSB/CCP2	= 16
9	RE1/AN6/VR	RC2/CCP1	= 17
10	RE2/AN7/CS	RC3/SCK/SL	= 18
		RC4/SDI/SDA	= 23
1	MCLR/Vpp/THV	RC5/SDO	= 24
		RC6/TX/CK	= 25
		RC7/RX/DT	= 26
		RD0/PSP0	= 19
		RD1/PSP1	= 20
		RD2/PSP2	= 21
		RD3/PSP3	= 22
		RD4/PSP4	= 27
		RD5/PSP5	= 28
		RD6/PSP6	= 29
		RD7/PSP7	= 30

Figure 34 Proteus Pic

- Pins 13/14 – Oscillator in/out
- RA0/AN0 – Temperature Sensor Input
- RE0/AN5RD – LED Connection
- MCLR/VPP/THV
- RC2/CCP1
- RC6/TX/CK
- RC7/RX/DT
- RD0/PSP0
- RD1/PSP1
- RD2/PSP2
- RD3/PSP3
- RD4/PSP4
- RD5/PSP5
- RD6/PSP6
- RD7/PSP7

3.7 LCD Display Specification

Incorporating an LCD into projects enables the end user to view temperatures, this helps understand what temperatures are around the working electronic components. Also by understanding how the set up works the end user should know what speed the motor should be running at. The micro controller sends out signals and data from 7 pins the LCD Display,

<u>Connection LCD Pins</u>	<u>Function</u>	<u>Cable Colour</u>
1	Ground	Black
2	5v DC Power	Red
4	RS	Pink
5	RW	Blue
6	Enable	White
11	Data 4	Purple
12	Data 5	Purple
13	Data 6	Purple
14	Data 7	Purple

The LCD screen will read the changing temperature values, when a command is sent from software it will read the temperature across the display.

3.8 Temperature Control / Analog to Digital Conversion

The sensor used in this project is an analogue temperature sensor, basically it senses its surrounding temperature and then outputs a voltage which corresponds. So as the temperature increases so will the output voltage, and as temperature decreases likewise will the voltage. The temperature will have a Linear relationship with the output voltage. In other words, a change in temperature will correspond with a change in output voltage over the sensors range of measurement.

This voltage output from the temperature sensor is required to activate a chain of events within the control system such as a fan speed increase or a valve opening for cooling.

But this output voltage from the temperature sensor needs to be converted. The input to micro controller is converted so it is understood by the controller, this is called Analogue to Digital conversion. For this the binary counting structure is used.

"For instance say we have a simple two bit system. The maximum count will be two to the second power or four (ranging from zero to three). The first bit will represent a two to the zero power or one, the second bit will represent a two to the first power or two. The way this system will count is shown below:

2-Bit Binary No. ____ Bits it represent ____ How it counts ____ Decimal Equivalent

0 0 ____ 0 ____ 0 + 0 ____ 0

0 1 ____ 1 ____ 0 + 1 ____ 1

1 0 ____ 1*2 ____ 2 + 0 ____ 2

1 1 ____ 1*2 + 1 ____ 2 + 1 ____ 3

Now, let's say we had a two bit analog to digital converter which can accept a maximum analog value (input voltage) of five volts. The converter will read a voltage value and assign it a binary number value between zero and three. It evenly divides the five volt span into these four chunks or sections. The important thing to remember here is that an analog value can vary as much as 1.25 volts (five divided by four) before it will increase a binary number value.

The reason this is important is for understanding the resolution of an analog to digital system. For instance let's say that we have another analog to digital converter but this one has **ten bit** resolution instead of the two bit one above. Our resolution now has 2 to the tenth power or 1024 steps (from 0 to 1023). Now divide that five volts maximum input by 1024 (total number of steps) and you can see the increased resolution this system brings. (Another note to mention is an eight bit system is 2 to the eighth power, or 256 steps).

This is important in cases where you want high resolution, or the ability to discern between small changes in readings (or how fine a resolution you want for a temperature sensor).

Another way to think of this is imagine you want to measure distance with a tape measure. The tape measure is divided into 1/32 of an inch so you can absolutely verify a reading to that accuracy. Now say you use a tape measure whose markings are only every inch (i.e. just a blank tape background between the inch numbers, no markings). Now you can only measure something to within one inch of accuracy because of the decreased resolution of the tape measure."

This project is using a 5 volt output temperature sensor, this will need to be converted so the micro controllers software can read the value and activate a sequence of commands. The microcontroller

has the capacity for a 10-bit analogue to digital converter.

So the temperature sensor is sensing the temperature converting that value to a voltage output to the input of the micro controller. The input pin is the 10 bit analogue to digital converter pin which has a maximum input voltage limit of 5 volts. Now we have a converted voltage which is symbolized in binary which would be between 0-1023. This is easily read by the micro controller and used to start operations.

So our converter assumes that 5 volts is 1023, it also assumes that something less than the 5volts will be in ratio between 5 volts and 1023.

Here are some equations that helped understanding Analogue to digital become a little easier. Here we have the resolution of the ADC divided by the system voltage equaling the ADC over Analog voltage measured.

$$\frac{\text{Resolution of the ADC}}{\text{System Voltage}} = \frac{\text{ADC Reading}}{\text{Analog Voltage Measured}}$$

As the system voltage is 5 volts, the ADC which is 1023 we dividing 1023 by 5 volts.

$$\frac{1023}{5} = \frac{\text{ADC Reading}}{\text{Analog Voltage Measured}}$$

The system voltage sometime could change so its just a case of changing that in the equation.

the analog voltage is 2.12V

$$\frac{1023}{5.00V} = \frac{x}{2.12V}$$

Rearrange the equation and we get:

$$\frac{1023}{5.00V} * 2.12V = x$$

$$x = 434$$

3.9 Motor Control

The main principles from this project are to successfully control the speed of a dc motor through the means of pulse width modulation. DC motors have been used when varying the speed of a motor for a long time. Dc motors are versatile with one of its main characteristics being it has a high starting torque. Speed control of a DC motor can be achieved at a lower cost in comparison to other motors such as alternating current motors and also relatively simpler at both low and high speeds. In this project speed control is achieved with Pulse Width Modulation and the generation of the Pulse Width Modulation is from a Micro controller.

Pulse Width Modulation is a technique by means of generating binary signals which has 2 periods of signals. These are a High signal and a Low signal. Also the width of the signal or pulse is varied depending on period with its main objective being to vary the control of the power depending on the duty cycle required from the input and the software.

(1) "Here the conduction time to the load is controlled. Let for a time t_1 , the input voltage appears across the load i.e. ON state and for t_2 time the voltage across the load is zero.

- The average voltage at output is given by

$$V_a = V_{max} \cdot$$

Where,

T_{ON} = Time period for Pulse ON,

T_{OFF} = Time period for Pulse OFF

- The average load current $I_a = V_a/R = kV_s/R$ where, T is the total time period $=t_1+t_2$, $k = t_1/T$ is the duty cycle.
- The duty cycle can be varied from 0 to 1 by varying t_1 , T or f . Therefore, the output voltage V_0 can be varied from 0 to V_s by controlling k , and the power flow can be controlled.

- As the time t_1 changes the width of pulse is varied and this type of control is called pulse width modulation (PWM) control.

For better understanding of PWM these diagrammatic representations can be used. These figures represent the waveforms obtained as output at different voltage requirements.

High Speed Signal (90%) In the project 90% duty would be required as it would fall into the highest temperature range between 36-40 degrees. The green part of the signal represents the ON time and the white part of it represents time when it is not receiving any voltage

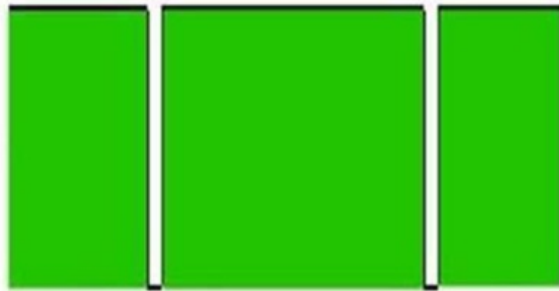


Figure 35 PWM DUTY

Signal with half voltage (50%) During this range the temperature would be between 26-30 degrees with the motor at half its full potential.



Figure 36 PWM DUTY

When using Pulse Width Modulation the average value of the voltages is specified to control the dc motor speed. The desired voltage is sent from the micro controller to Dc motor via pulse width modulation and then it varies the motor speed.

The chosen micro controller must have a Pulse Width Modulation option, some micro controllers do not have the capacity for Pulse Width Modulation. When the correct choice of micro controller is chosen, depending on the input value given for generating the Pulse Widths for varying motor speeds. To test or simulate the project in the Proteus design a Variable Resistor has been allocated instead of a sensor to fully test the Modulation at desired temperatures. With the help of the potentiometer the input value is given to the Micro controller. The potentiometer is given a 5v supply with the other two connections one grounded and the other becoming the varied voltage output from the potentiometer to the micro controller. The micro controller using Analogue to digital conversion converts the analogue value which is between 0-5v dc to a digital value. The written software and micro controller then processes the input voltage from the potentiometer to generate the Pulse Width Modulation. The program for generating the Pulse Width was generated in CCS and stored on the micro controller's internal memory.

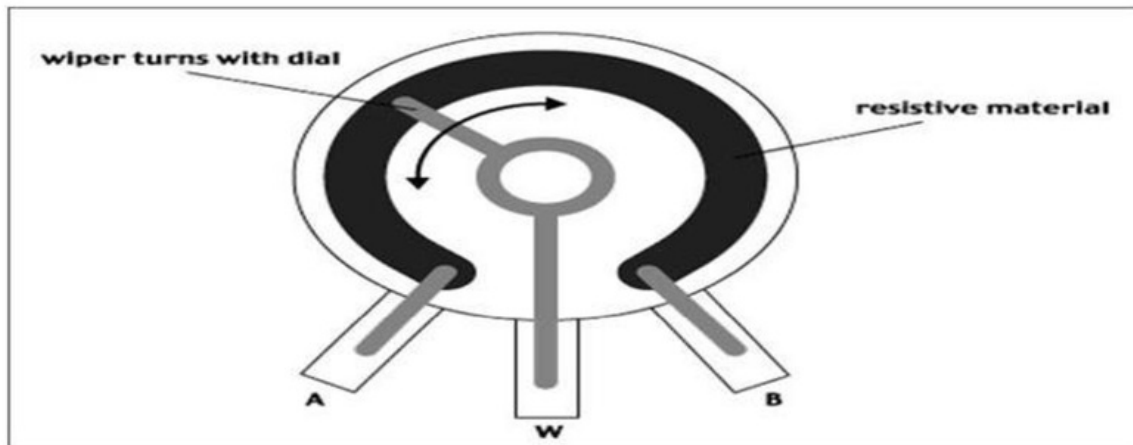


Figure 37 Potentiometer

The Analogue to digital converter (ADC) pin on the microcontroller receives the varied voltage and converts it into a 10 bit value in binary. The binary value is then converted in accordance the decimal range of 0-1023. This then generates the output pin on the micro controller which in this case happens to be RC2/CCP1. It is generated for a time period depending on changing temperature values.

3.10 Software Architecture

The software was initially started using the software CCS, this is where the desired operation of the project is programmed. Once there is a clear idea of how the project is supposed to operate it is possible to start writing code. To create the program it is important to understand the PICs capabilities to understand what pins do what. For this project, Analogue to Digital conversion was required and needed to be set up in the software, along with PWM output PIN. In total for the completion of this projects software there is a total of 96 lines of code, which are relatively easy understand. The design of the project required temperature values to be sent to the LCD, this is also done in the software.

Below are some pictures of certain areas of the code that have been created in order to control the speed of the motor with relation to the temperature.

3.11 Software LCD Set-Up

Below is the code given to initialize the set up for the LCD screen which includes setting up each PIC pin.

LCD Pin 4 – RS is connected to PIC PIN 19 RD0/PSP0
LCD Pin 5 – RW is connected to PIC PIN 20 RD1/PSP1
LCD Pin 6 – Enable is connected to PIC PIN 21 RD2/PSP2
LCD Pin 11 – Data 4 is connected to PIC 27PIN RD4/PSP4
LCD Pin 12 – Data 5 is connected to PIC 28PIN RD5/PSP5
LCD Pin 13 – Data 6 is connected to PIC 29PIN RD6/PSP6
LCD Pin 14 – Data 7 is connected to PIC 30PIN RD7/PSP7

```

1  #include <main.h>
2  #define LCD_ENABLE_PIN PIN_D2
3  #define LCD_RS_PIN PIN_D0
4  #define LCD_RW_PIN PIN_D1
5  #define LCD_DATA4 PIN_D4
6  #define LCD_DATA5 PIN_D5
7  #define LCD_DATA6 PIN_D6
8  #define LCD_DATA7 PIN_D7
9
10 #include <lcd.c>
11
12 void main()
13 {

```

So it's clear from the above images what PIN is being set up in the software and what its connected to on the LCD display physically. If this set is incorrect the messages/values required to be sent to the LCD screen will not be correct hindering the operation of the project.

3.12 Initialising the ports

```

setup_adc_ports(RA0_analog);
setup_adc(adc_clock_internal);
set_adc_channel(0);
lcd_init();
printf(lcd_putc, "\n");
delay_ms(1000);
for(;;)
{

```

The above figure shows the initial set up of the ADC port and internal clock. This is a requirement of the pic as an internal oscillator isn't present. It also shows the LCD initialisation, a demand is set so the LCD screen initialises on power.

```
temp = (float) read_adc()/2;
if (temp >= 20 && temp <= 25)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(31);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 25);
    delay_ms(1000);
}
else if (temp >= 26 && temp <= 30)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(62);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d ", 50);
    delay_ms(1000);
}
```

In this figure it shows the PWM set up. This is required with PIC 16f877, it needs to be instructed that PWM output is going to be utilised. As the PWM is allocated to pin CCP1 it then shows the timer and delay associated and the software looking for the input ADC value.

3.13 Proteus Build

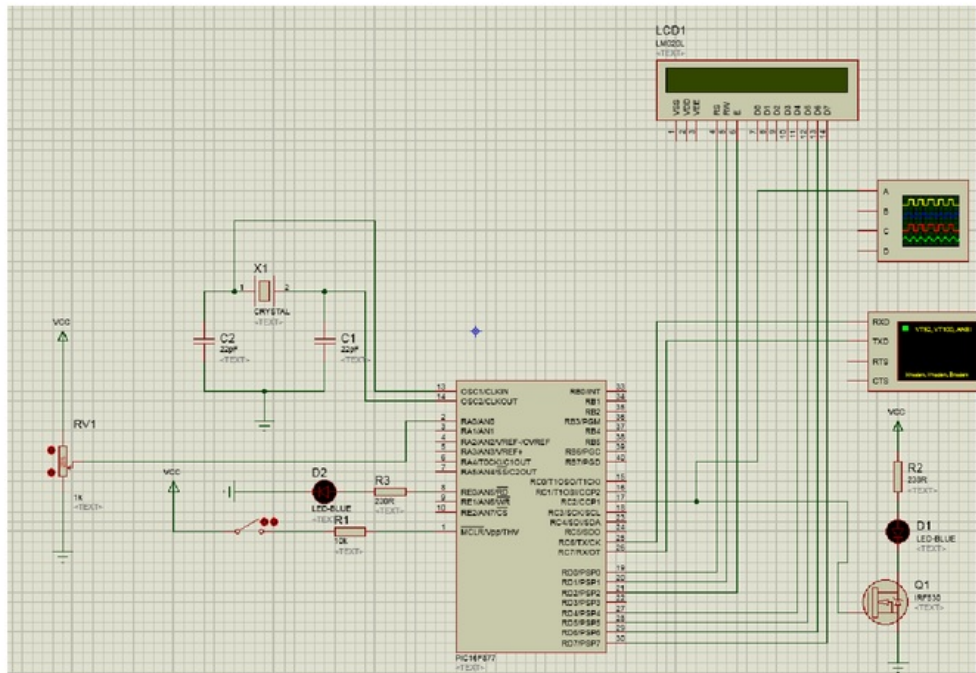


Figure 38 Proteus build

3.14 Proteus Build Components

Here is the breakdown of the Proteus circuit design elements.

3.15 Oscillator

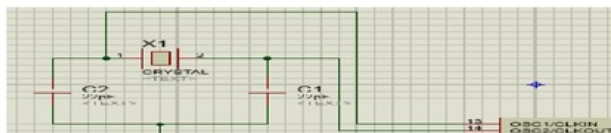


Figure 39 Oscillator

As the pic chosen doesn't have an internal clock (Oscillator) a crystal will be implemented with two 22pF capacitors to provide clock speed for execution of the project. It is connected into OSC1/CLKIN PIN 13 and OSC2/CLKOUT PIN 14.

3.16 Power Switch and LED

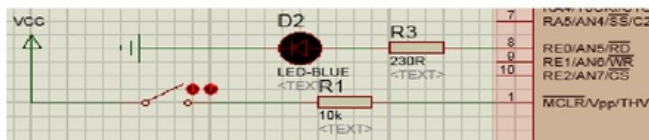


Figure 40 Power Switch

Here we have the power switch with an inline resistor of 10K, this enables the end user to operate the power to the PIC On/Off. Also the LED, this used to prove that the pic is being provided its excitation required. It is an indicator if ever fault finding is required to prove the pic is receiving power.

The main power switch is connected the PIN 1 MCLR/Vpp/THV. The LED is an output from the pic which is connected to PIN 8 RE0/AN5/RD. Below the power switch is closed.



Figure 41 MSTR Clear

Here is the LED lit, proving power to our PIC.

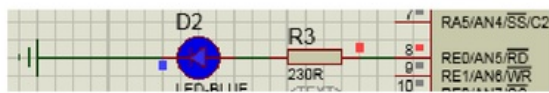


Figure 42 Power Prooving LED

3.17 Variable Resistor (Temperature Simulation)

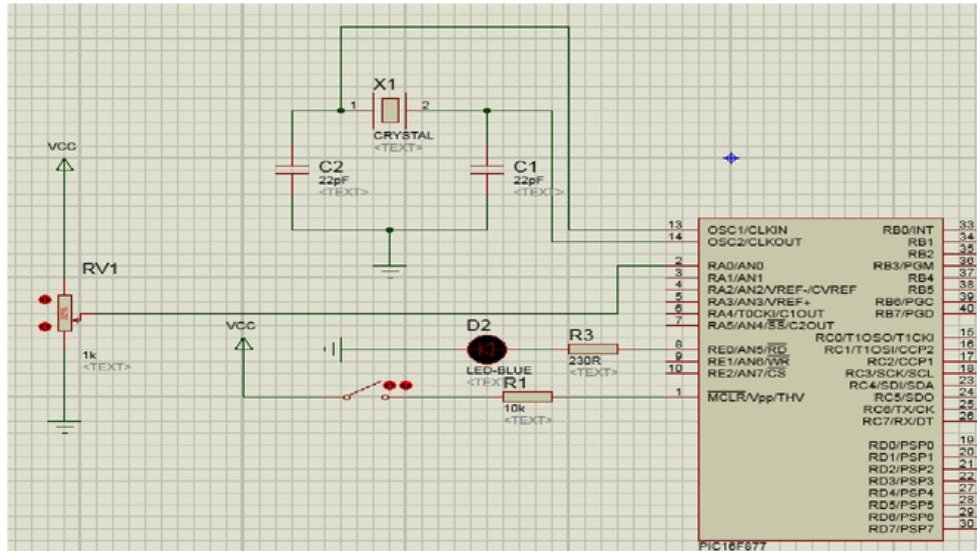


Figure 43 Variable Resistor Proteus

To simulate the temperature to the ADC, a Variable resistor is used to vary the input voltage to PIN 2 RA0/AN0. Then from the value given from the variable resistor an analogue to digital conversion is made and a PWM output signal is then sent to the motor to drive it at a set duty.

Below is showing the simulation of the variable resistor in percentage.



Figure 44 Variable Resistor Proteus

3.18 PWM Output to Motor

Below is the Proteus design of the PWM output from PIN 17 RC2/CCP1, instead of using a motor we are using a flashing LED to simulate the motor speed. Depending on the temperature the LED would flash at certain speed depending on the software PWM output duty.

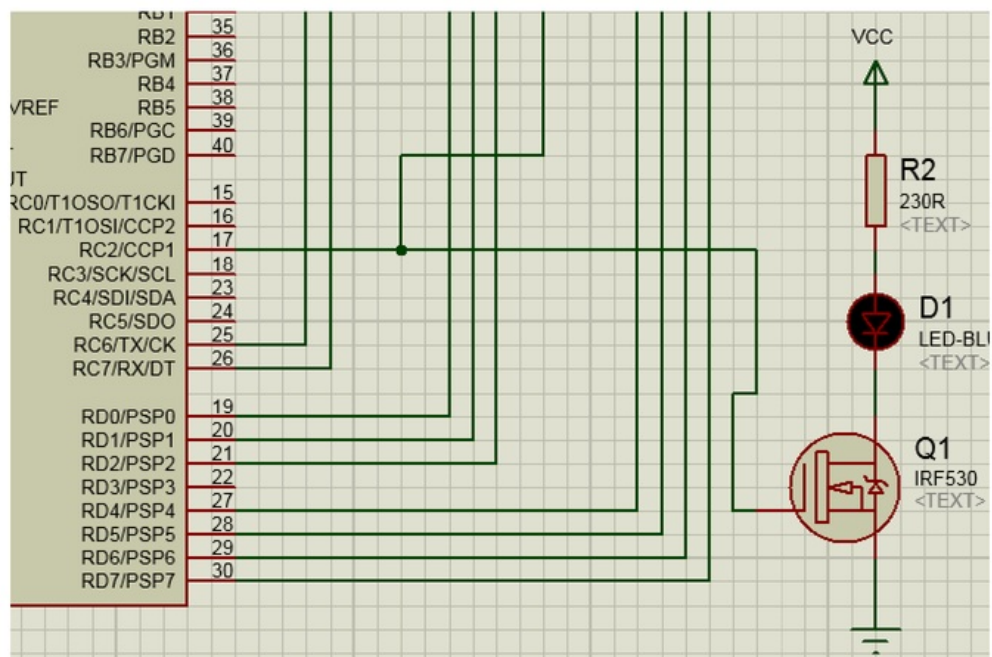


Figure 45 PWM Output

3.19 Virtual Terminal

The virtual terminal is used to view the temperature values from the PIC. It is connected to the PINs 25 RC6/TX/CK and 26 RC7/RX/DT, these are the transmitter and receiver PINs that connect to the virtual terminal. Data can be taken from these and logged or stored via SD Card or through RS232.

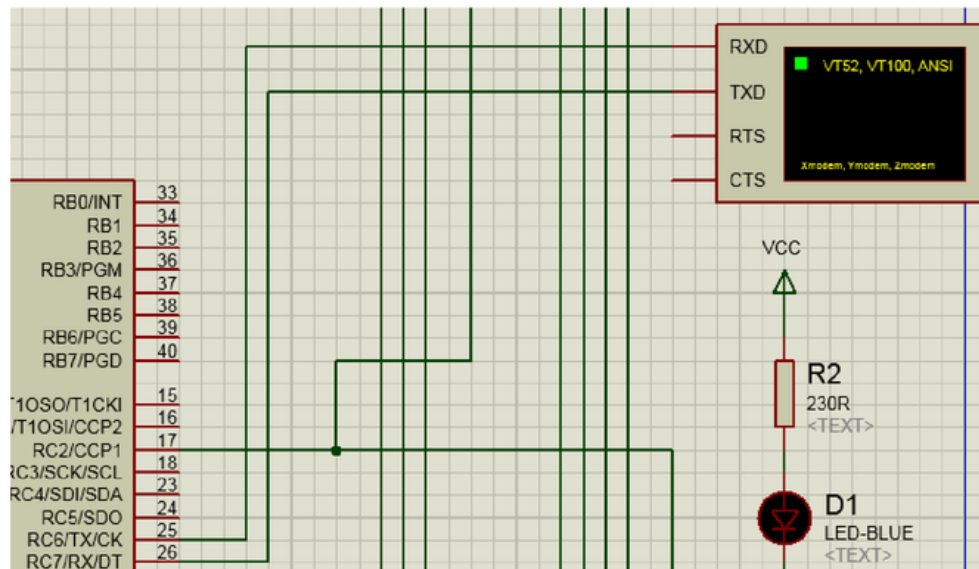


Figure 46 Virtual Terminal

3.20 Digital Oscilloscope

In the Proteus design designed a digital oscilloscope has been utilised to measure the PWM outputs to compare with temperature. This is useful in testing the software and being able to physically see the PWM outputs changing digitally.

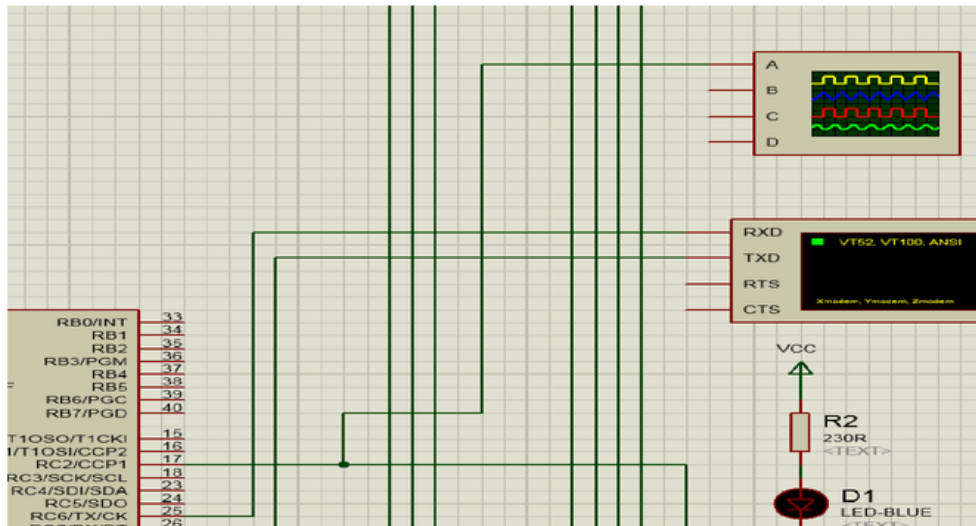


Figure 47 Proteus Oscilloscope

3.21 LCD

The LCD is used to show changing temperature values from the PIC. This is extremely useful as it is a visual way to see the temperature change and proving the correct operation of the PIC in relation to the temperature to the PWM output. A 5v supply and ground connection is required. Along with connections;

LCD Pin 4 – RS is connected to PIC PIN 19 RD0/PSP0
LCD Pin 5 – RW is connected to PIC PIN 20 RD1/PSP1
LCD Pin 6 – Enable is connected to PIC PIN 21 RD2/PSP2
LCD Pin 11 – Data 4 is connected to PIC 27PIN RD4/PSP4
LCD Pin 12 – Data 5 is connected to PIC 28PIN RD5/PSP5
LCD Pin 13 – Data 6 is connected to PIC 29PIN RD6/PSP6
LCD Pin 14 – Data 7 is connected to PIC 30PIN RD7/PSP7

These are vital when setting up LCD in the software. It is important that the correct pins are also connected physically to where they should be or commands and data cannot be sent to the LCD

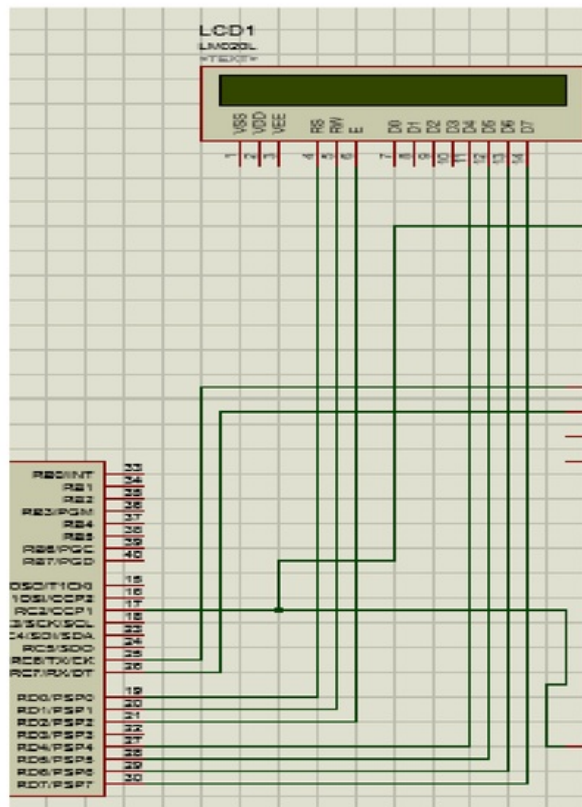


Figure 48 LCD

From researching the LCD and PIC pins, the display can be wired correctly and configured to receive data correctly in the software.

4.0 Chapter 4

4.1 Evaluation

To simulate the software in proteus, an Led was used as the motor to show the running speeds. Also a variable resistor was used instead of the LM35 to simulate voltage output to the pic. By varying the voltage from the resistor we could simulate PWM output at certain temperatures testing the software in the process. Using an oscilloscope and virtual terminal to complete the testing.

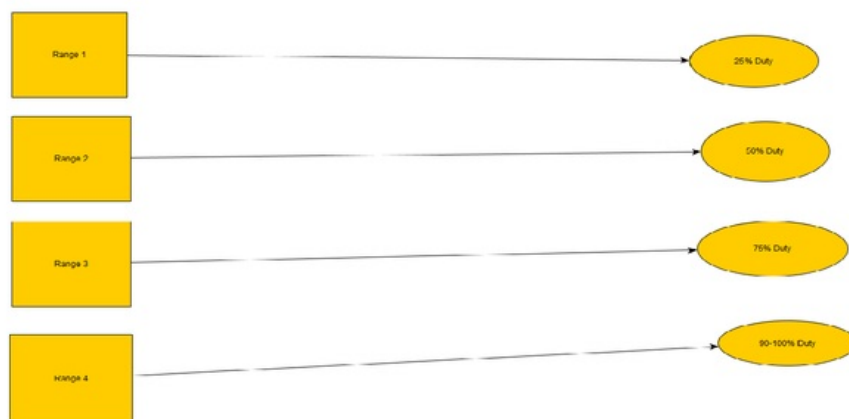


Figure 49 PWM Flow Chart

Here are the ranges where the PWM output would control the duty of the motor depending on the temperature reading from the LM35.

During the testing and evaluation stage the program created in ccs was downloaded to micro controller using the Pikit 3 device. The device was connected to Micro controller and using MPLAB software the program was downloaded to microcontroller straight forward.

4.2 Simulation Above Temperature Range

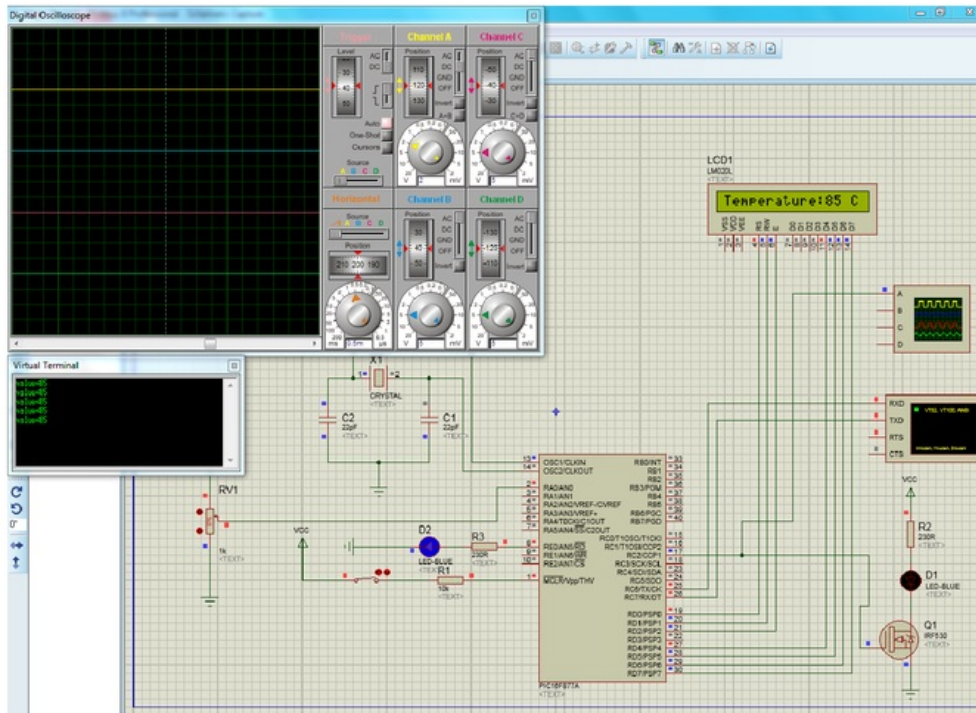


Figure 50 Proteus Simulation

The desired operation of the project means when the temperature falls outside of certain ranges then there is no PWM output from the pic. Here it clearly shows that the temperature is above 85 degrees Celsius. By this being above our temperature range the motor should not run, there should be no output from the pic.

4.3 Software above range

```
else if ((temp < 20) || (temp > 40))
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(0);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\r");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nToo low/high temp !!");
    output_high(pin_c0);
    delay_ms(1000);

}

printf("value=%d\n\r", temp);

//TODO: User Code
}
```

From the software code it shows that anything reading above 40 degrees Celsius the PWM output should be at 0. This is because due to operating temperatures and the likely case that the temperature is too hot for even the fan to cool down. Meaning the device should be cleaned put in a well ventilated area and tested. The temperature reading is printed to LCD using the command seen above in the software Printf temperature.

4.4 Simulation Below Temperature Range

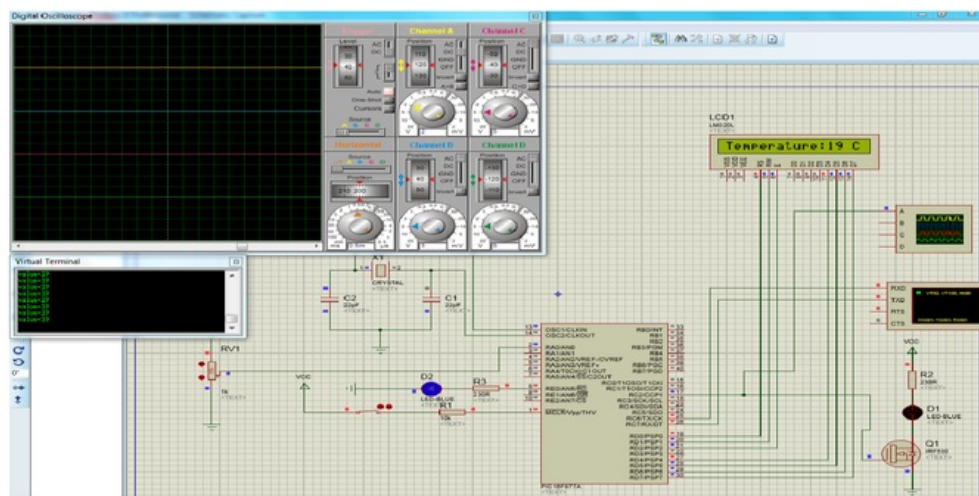


Figure 51 Proteus Simulation 1

Likewise with the temperature being lower than parameters set, if the temperature was below 20 degrees Celsius the motor is not required to run. Mainly because the system is cool enough and there is now demand for cooling .

From the above oscilloscope you can clearly see no PWM output from the micro controller, meaning the code created is correctly functioning and controlling the motor to its desired set points.

4.5 Software below range

```
else if ((temp < 20) || (temp > 40))
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(0);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\n");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nToo low/high temp !!");
    output_high(pin_c0);
    delay_ms(1000);

}

printf("value=%d\n", temp);

//TODO: User Code
}
```

From the above code we can see that if the temperature is below 20 degrees Celsius then the motor is not required to run, a print message is sent to LCD showing the current temperature values. The user then knows that his device is within normal working temperature parameters.

4.6 Simulation Temperature Range 1

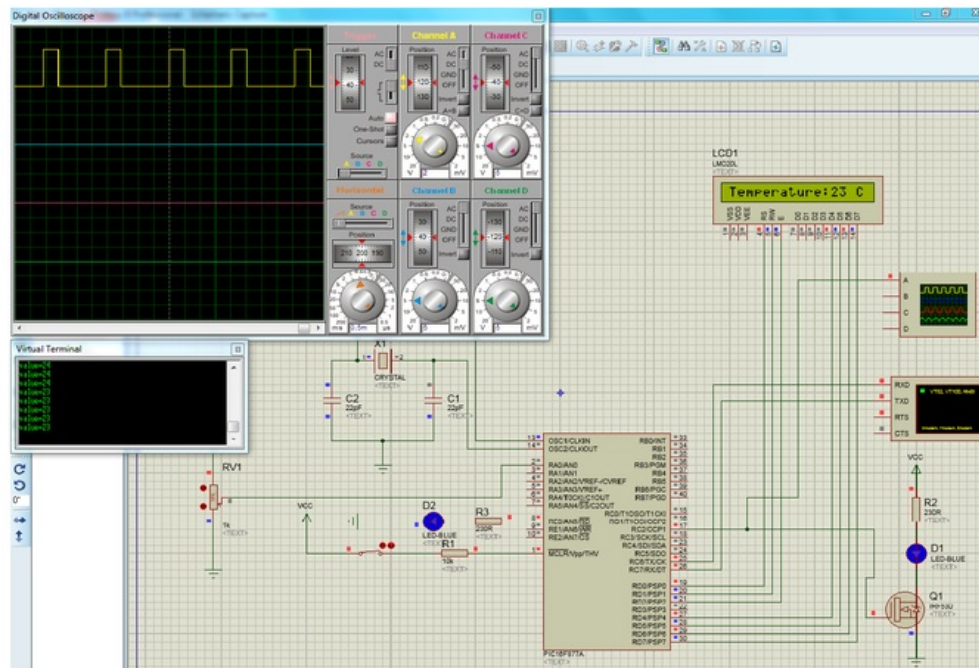


Figure 52 Proteus Simulation 2

From this simulation when the temperature is above 20 degrees Celsius but below 25 degrees Celsius then PWM output should be at 31. This means that to motor duty should be running at 25% of its full potential. This should be sufficient to bring the temperature back down to below 20 degrees Celsius. Although from the figure you cannot see the speed of the LED flashing, you can see the Pulse width on the oscilloscope which indicates that motor should be running at 25% duty.

4.7 Software range 1

```
temp = (float) read_adc()/2;  
if (temp >= 20 && temp <= 25)  
{  
    setup_ccp1(ccp_pwm);  
    set_pwm1_duty(31);  
    setup_timer_2(t2_div_by_16, 127, 1);  
    printf(lcd_putc, "\f");  
    printf(lcd_putc, "Temperature:%d C", temp);  
    printf(lcd_putc, "\nDuty Cycle : %d", 25);  
    delay_ms(1000);  
}
```

Above is the code written for the temperature range 1. So when temperature is above 20 degrees Celsius and below 25 degrees Celsius the motor PWM output should be at 31. Meaning that the motor should run at 25% of its full potential. Also the above temperature reading is sent to LCD display.

4.8 Simulation Temperature Range 2

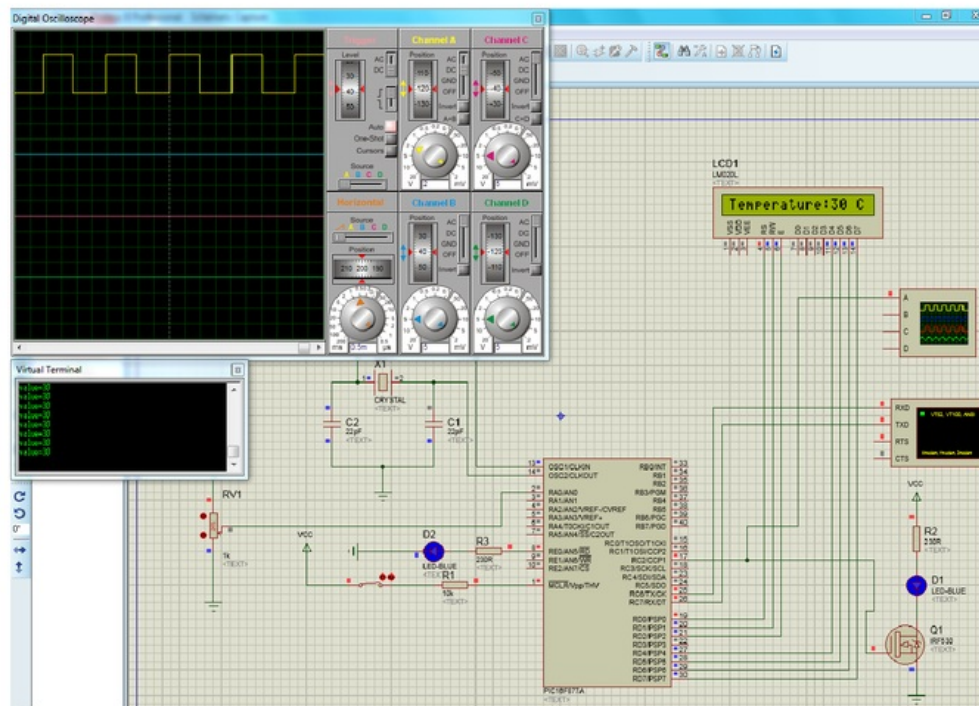


Figure 53 Proteus Simulation 3

Above is the simulation for temperature range 2, here when the temperature is 26 degrees Celsius or above and 31 degrees Celsius and below the PWM output should be at 64 meaning the motor should run at 50% its full potential. Meaning the temperature is starting to get hot and increasing the motor speed should reduce the temperature before any damage is committed. Again it isn't clear from the LED status that the motor should be running at 50% but by the digital oscilloscope showing the 50% duty for the PWM output it proves the software is operating to correctly to the set temperature and desired operation.

4.9 Software Range 2

```
else if (temp >= 26 && temp <= 30)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(62);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d ", 50);
    delay_ms(1000);
}
```

From the software written above it is clear that when the temperature is at 26 degrees or at 30 degrees and below the PWM output should be set at 64 meaning the motor runs at 50% of its full potential. The temperature value at that current time is sent to the LCD display.

4.10 Simulation Temperature Range 3

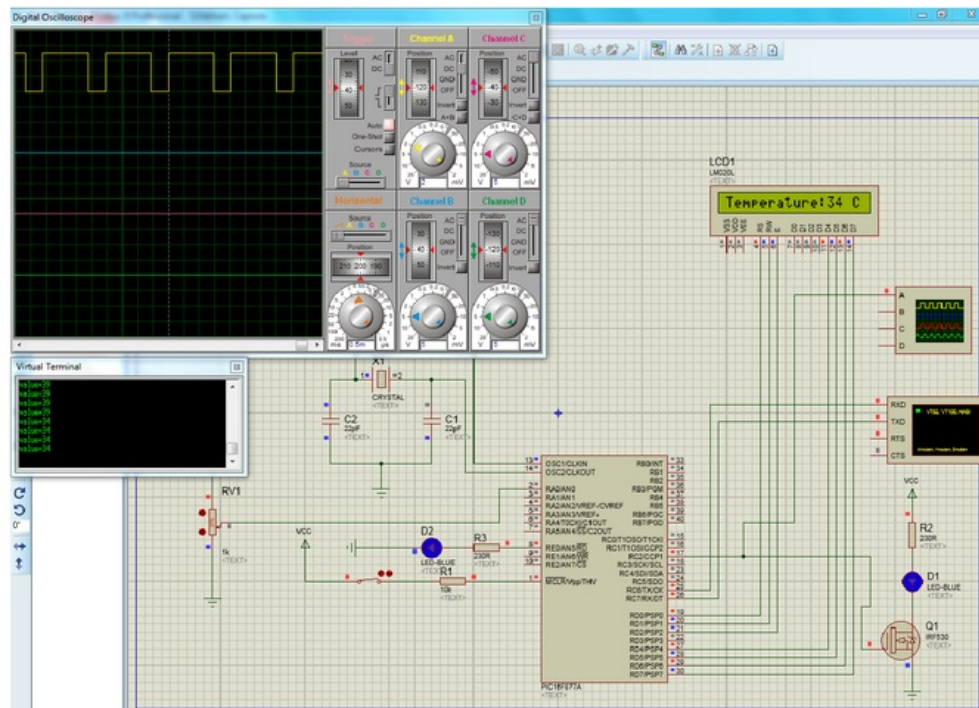


Figure 54 Proteus Simulation 4

The above simulation is for temperature range 3, for this simulation when the temperature is 31 degrees and above or 35 degrees and below the pulse width modulation should read at 93. Meaning the temperature reading requires cooling and the motor should be running at 75% of its full potential. As the LED doesn't prove the simulation has worked then the screen shot of the PWM output from the pic to the digital oscilloscope should show the software is operating correctly within its set parameters.

4.11 Software Range 3

```
else if (temp >= 31 && temp <= 35)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(93);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 75);
    delay_ms(1000);
}
```

From the software code written above, it is setup so that if the temperature is at or above 31 degrees Celsius or at 35 degrees and below the PWM output should be set at 93. This meaning the PWM Output is at 75% meaning the motor is running at 75% duty of its full running potential. The temperature is then printed to LCD display.

4.12 Simulation Temperature Range 4

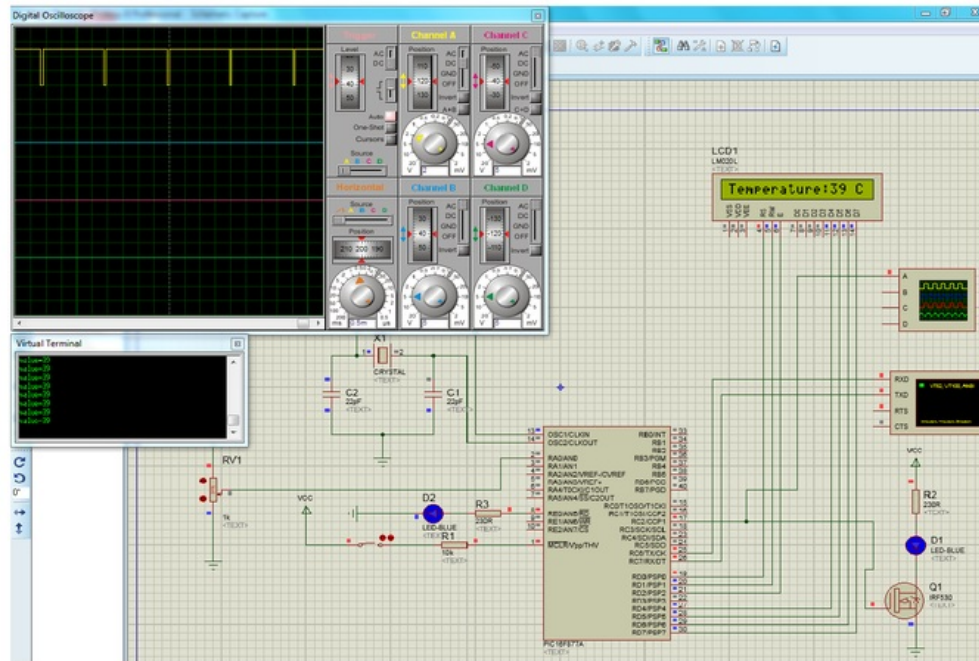


Figure 55 Proteus Simulation 5

The above simulation is for temperature range 4, for this simulation when the temperature is 36 degrees and above or 40 degrees and below the pulse width modulation should read at 124. Meaning the temperature reading requires cooling and the motor should be running at 100% of its full potential. As the LED doesn't prove the simulation has worked then the screen shot of the PWM output from the pic to the digital oscilloscope should show the software is operating correctly within its set parameters. Now the motor should be cooling the device at full potential.

4.13 Software Range 4

```
else if (temp >= 36 && temp <= 40)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(124);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 90);
    delay_ms(1000);
}
```

From the software code written above, it is setup so that if the temperature is at or above 36 degrees Celsius or at 40 degrees and below the PWM output should be set at 124. This meaning the PWM Output is at 100% meaning the motor is running at 100% duty of its full running potential. The temperature is then printed to LCD display.

From the data received in the simulation testing it clearly shows the software operating to its designed parameters with PWM outputs changing in relation to the temperature change. Therefore the temperature was controlling the motor speed through pulse width modulation.

4.14 Proteus and Software Issues

During the proteus and code software architecture a few problems arose.

- Software – when testing the code in proteus it was clear at the beginning there were issues, as nothing would function correctly except the LED coming on for power. Below is an example of code written, in red is the temperature range. As the signals were mixed on the digital oscilloscope and checking the code it was found that a simple error had occurred. As you can see the Arrows showing greater than 26 and greater than 30. This was clearly wrong and a quick adjustment was made to overcome this problem.
- ```
else if (temp >= 26 && temp >= 30)
```
- ```
{
```
- ```
 setup_ccp1(ccp_pwm);
```
- ```
    set_pwm1_duty(62);
```
- ```
 setup_timer_2(t2_div_by_16, 127, 1);
```
- ```
    printf(lcd_putc, "\n");
```
- ```
 printf(lcd_putc, "Temperature:%d C", temp);
```
- ```
    printf(lcd_putc, "\nDuty Cycle : %d ", 50);
```
- ```
 delay_ms(1000);
```
- ```
}
```
- Software - another issue with the code was the lower and upper range temperatures. As seen below the code was written wrong and the simulations were not running correctly. As you can see from the software below the logic is wrong, written code is saying if temperature is below 20 AND above 40. Clearly this is impossible, either the temperature is

above or below as there is only one temperature value. A quick logic change was made to complete the code correctly and it now looks like `((temp < 20) || (temp > 40))`

- `else if ((temp < 20) && (temp > 40))`
- `{`
- `setup_ccp1(ccp_pwm);`
- `set_pwm1_duty(0);`
- `setup_timer_2(t2_div_by_16, 127, 1);`
- `printf(lcd_putc, "\f");`
- `printf(lcd_putc, "Temperature:%d C", temp);`
- `printf(lcd_putc, "\nToo low/high temp !!");`
- `output_high(pin_c0);`
- `delay_ms(1000);`
-

Other issues occurred with printing the commands to the LCD screen, such as brackets missing and incorrect spacing. Also the original setting up of the PWM port was tricky as it isn't designed just for PWM. Data sheets were read and other examples of code examined to find that this was how the PWM port was set up and allocated. Also setting up the pin for ADC.

```
setup_adc_ports(RA0_analog);
```

```
setup_adc(adc_clock_internal);
```

```
set_adc_channel(0);
```

```
lcd_init();
```

```
printf(lcd_putc, "\f");
```

```
delay_ms(1000);

for(;;)

{

    temp = (float) read_adc()/2;

    if (temp >= 20 && temp <= 25)

    {

        setup_ccp1(ccp_pwm);
```

- Hardware issues have also occurred during the build such as being unable to get the LCD operating , clearly from the software simulation that is operating correctly but not physically. It will Require further investigation over the coming days. It could be a faulty LCD or faulty pins on the micro controller itself, further testing will reveal the issues.

5.0 Chapter 5

5.1 Conclusion

At the start of this project there were some key areas aims and objectives that were set out to work on. The finished project was set up to read temperature values and depending on the temperature in given ranges control a dc motor using pulse width modulation output from the microcontroller.

Also whatever to the temperature reading, it must be displayed on the LCD regardless if it was in any of the set ranges as the end user is to always know the internal temperature of the device. So for example if the temperature was below 20 degrees Celsius or above 40 degrees Celsius the motor doesn't run but the display would still show the internal temperature as long as there is power on the device. The proto type was built on breadboard, but if this device were to be used in industry designing a PCB and decreasing its size would help this product sell more as it could then potentially fit in most manufacturers products.

This could improve life span of products and improve the end users relationship and trust in consoles and laptops/computers or any device where electronics are present.

The price range of this design would likely be rolled out at £10 – 20 sterling. It would not be an expensive device but an important component of the device it is installed into.

At the time of the hand in for this written report the physical build is not fully operational and requires further testing, but the author is happy that the software and circuit design using Proteus is correct and functional to the design set in this report.

The author concludes that this device could dramatically improve life span of consoles laptops and other electronic devices and intrust the customers and end users would receive full value for money and guarantee a longer life span for their device.

5.2 Recommendations and Possible Improvements

Below are a few suggestions which could improve the design if found necessary:-

Improvement 1 – Wireless Sensors

By using wireless sensors this could improve the system. Less wires being fed around the enclosure and creating less current output. This would be an ideal improvement as long as the sensors transmitters/Receivers were reliable.

Improvement 2 – Logging Data

Adding an internet connection or radio control to the product would add the possibility of controlling and monitoring this device remotely. Also real time data could be recorded as well as logging data.

Improvement 3 – Battery Life

To increase battery life using a solar panel or wind turbine on the device would generate its own energy. Or by using rechargeable batteries that could be charged through these energy sources.

Improvement 4 – BMS

It could be incorporated into a building management system. It could share data such as air temperature creating less I/O for both systems. Inside air temperature data could be shared. So end user could compare and monitor the of data. The BMS using the outside air temperature could then enable frost conditions or summer conditions depending on the temperature. Therefore energy saving ideas could be generated.

Improvement 5 – Trend Logging

If a trend logging system could be installed into the system this would allow the user to record and analyse the data received. Monitor readings to further improve the system and performance.

Improvement 6 - GPS

A GPS module included in the design as some of the researched loggers utilise, would allow the logger to locate its position if required.

Improvement 7- Web Based Loggin System

A Web-based data logging system would enable remote monitoring through Wi Fi or Ethernet! A web server could be created and the data could be monitored online. Also the system could then email results and data out to users live.

Improvement 8 - Bluetooth

Bluetooth – This would enable the data logger to transmit the data recorded to a mobile or Bluetooth device within a certain distance of the system.

Improvement 9 – Alarming System

An alarming system could be set up, this would allow the user to see if there are any problems with the system in real time. Using Leds or sounders this could be a cheap installation that would enhance the system and help end user realised when the temperature of the device was at a critical level. Incorporating a two tier LCD to display all alarms and temperatures.

Improvement 10

By adding a cooling valve or some form of radiator over the fan so it could fluctuate cold air. By using PWM you could modulate the valve open or closed depending on the temperature similar to the operation of motor.

6.0 Chapter 6

6.1 Reflection

Completing this project has dramatically improved my knowledge and helped me understand more about electronic design. It has helped me understand how to set up projects and design an automated control system from using micro controllers and integrating components such as sensors, motors and LCD's.

Also in completing this project I have learned the process of pulse width modulation and analogue to digital conversion and has improved my knowledge on binary counting. An important tool gained from this project is how to source and select a suitable micro controller for a specific design and implement into a circuit to control such a system. Also learning and understand the art of code and programming the micro controller using C language.

From now, I will further my knowledge of micro controllers and continue to develop my skills by completing homemade projects and trying to encourage my employer to use micro controllers in some smaller design systems that we use on smaller sites such as care homes and smaller structures.

During this project I have learned a lot about myself, at points during this project I didn't believe I would finish or understand fully what was required to complete it. I am quite proud of my achievements, but accept there is a lot more to be learned and hope that after this course is complete my learning doesn't stop there. I have thoroughly enjoyed completing this project and would like to thank UWTSD and the lecturers involved for making this an enjoyable part of my life.

I would consider coming back and completing my masters, I have thoroughly enjoyed my time studying at UWTSD and if my employer were to let me have day release over the next few years I will most certainly be coming back.

Thank you.

7.0 Chapter 7

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8.0 Chapter 8 Appendix

8.2 Written Code

```
#include <main.h>

#define LCD_ENABLE_PIN PIN_D2

#define LCD_RS_PIN PIN_D0

#define LCD_RW_PIN PIN_D1

#define LCD_DATA4 PIN_D4

#define LCD_DATA5 PIN_D5

#define LCD_DATA6 PIN_D6

#define LCD_DATA7 PIN_D7


#include <lcd.c>


void main()
{

    setup_adc_ports(AN0);
    setup_adc(ADC_CLOCK_INTERNAL);


    lcd_init();

    int temp;

    while(TRUE)
    {

        //Example blinking LED program
        output_low(LED);
        delay_ms(500);
        output_high(LED);
        delay_ms(500);
```

```
setup_adc_ports(RA0_analog);
setup_adc(adc_clock_internal);
set_adc_channel(0);
lcd_init();
printf(lcd_putc, "\f");
delay_ms(1000);
for(;;)
{
    temp = (float) read_adc()/2;
    if (temp >= 20 && temp <= 25)
    {
        setup_ccp1(ccp_pwm);
        set_pwm1_duty(31);
        setup_timer_2(t2_div_by_16, 127, 1);
        printf(lcd_putc, "\f");
        printf(lcd_putc, "Temperature:%d C", temp);
        printf(lcd_putc, "\nDuty Cycle : %d", 25);
        delay_ms(1000);
    }
    else if (temp >= 26 && temp <= 30)
    {
        setup_ccp1(ccp_pwm);
        set_pwm1_duty(62);
        setup_timer_2(t2_div_by_16, 127, 1);
        printf(lcd_putc, "\f");
        printf(lcd_putc, "Temperature:%d C", temp);
        printf(lcd_putc, "\nDuty Cycle : %d ", 50);
        delay_ms(1000);
    }
    else if (temp >= 31 && temp <= 35)
```

```
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(93);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 75);
    delay_ms(1000);
}

else if (temp >= 36 && temp <= 40)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(124);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 90);
    delay_ms(1000);
}

else if ((temp < 20) || (temp > 40))
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(0);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nToo low/high temp !!");
    output_high(pin_c0);
    delay_ms(1000);
}
```

```
    }  
  
    printf("value=%d\n\r",temp);  
  
}  
  
}  
  
    //TODO: User Code  
}
```

8.2 Data Sheets

All data sheets will be placed onto a USB and submitted with written project.

```
    }  
    else if (temp >= 36 && temp <= 40)  
    {  
        setup_ccp1(ccp_pwm);  
        set_pwm1_duty(124);  
        setup_timer_2(t2_div_by_16, 127, 1);  
        printf(lcd_putc, "\f");  
        printf(lcd_putc, "Temperature:%d C", temp);  
        printf(lcd_putc, "\nDuty Cycle : %d", 90);  
        delay_ms(1000);  
    }  
    else if ((temp < 20) || (temp > 40))  
    {  
        setup_ccp1(ccp_pwm);  
        set_pwm1_duty(0);  
        setup_timer_2(t2_div_by_16, 127, 1);  
        printf(lcd_putc, "\f");  
        printf(lcd_putc, "Temperature:%d C", temp);  
        printf(lcd_putc, "\nToo low/high temp !!");  
        output_high(pin_c0);  
        delay_ms(1000);  
    }  
    printf("value=%d\n\r", temp);  
}  
  
    //TODO: User Code  
}
```

```
else if (temp >= 26 && temp <= 30)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(62);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d ", 50);
    delay_ms(1000);
}
else if (temp >= 31 && temp <= 35)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(93);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 75);
    delay_ms(1000);
}
else if (temp >= 36 && temp <= 40)
{
    setup_ccp1(ccp_pwm);
    set_pwm1_duty(124);
    setup_timer_2(t2_div_by_16, 127, 1);
    printf(lcd_putc, "\f");
    printf(lcd_putc, "Temperature:%d C", temp);
    printf(lcd_putc, "\nDuty Cycle : %d", 90);
    delay_ms(1000);
}
```

```
setup_adc_ports(RA0_analog);
setup_adc(adc_clock_internal);
set_adc_channel(0);
lcd_init();
printf(lcd_putc, "\f");
delay_ms(1000);
for(;;)
{
    temp = (float) read_adc()/2;
    if (temp >= 20 && temp <= 25)
    {
        setup_ccp1(ccp_pwm);
        set_pwm1_duty(31);
        setup_timer_2(t2_div_by_16, 127, 1);
        printf(lcd_putc, "\f");
        printf(lcd_putc, "Temperature:%d C", temp);
        printf(lcd_putc, "\nDuty Cycle : %d", 25);
        delay_ms(1000);
    }
    else if (temp >= 26 && temp <= 30)
    {
        setup_ccp1(ccp_pwm);
        set_pwm1_duty(62);
        setup_timer_2(t2_div_by_16, 127, 1);
        printf(lcd_putc, "\f");
        printf(lcd_putc, "Temperature:%d C", temp);
        printf(lcd_putc, "\nDuty Cycle : %d ", 50);
        delay_ms(1000);
    }
}
```

```
1  #include <main.h>
2  #define LCD_ENABLE_PIN PIN_D2
3  #define LCD_RS_PIN PIN_D0
4  #define LCD_RW_PIN PIN_D1
5  #define LCD_DATA4 PIN_D4
6  #define LCD_DATA5 PIN_D5
7  #define LCD_DATA6 PIN_D6
8  #define LCD_DATA7 PIN_D7
9
10 #include <lcd.c>
11
12 void main()
13 {
14     setup_adc_ports(AN0);
15     setup_adc(ADC_CLOCK_INTERNAL);
16
17     lcd_init();
18     int temp;
19     while(TRUE)
20     {
21
22         //Example blinking LED program
23         output_low(LED);
24         delay_ms(500);
25         output_high(LED);
26         delay_ms(500);
27     }
```